Making sense of research for sustainable land management

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Hanspeter Liniger, Rima Mekdaschi Studer, Peter Moll, Ute Zander

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Foreword

> "If you are planning for a year, sow rice; if you are planning for a decade, plant trees; if you are planning for a lifetime, educate people"
>
> (goes a Chinese proverb)

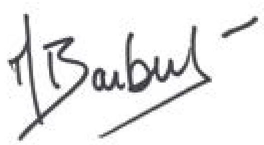
Since entering into force two decades ago, the United Nations Convention to Combat Desertification (UNCCD) has been supporting countries to sow and plant in a sustainable way, while focusing on people and communities as agents for change.

Where do we stand two decades later? For one, the importance of restoring degraded land and avoiding further land degradation is now largely recognized. The Sustainable Development Goals adopted by world leaders in 2015 call for achieving land degradation neutrality as one of the targets. Over 100 countries are now setting out ambitious national plans to turn these targets into reality.

So are people becoming agents for change? You will find the answer in this book. The book showcases how stakeholders – scientists, researchers, extension workers and farmers – collectively delivered sustainable land management, are combatting desertification and effectively curbing hunger and poverty. In Western Siberia, the finding by scientists of a potential to increase crop yields by 25% encouraged farmers to adopt no till/minimum tillage. Livestock herders in Madagascar learned through a nursery test how they can secure fodder by a simple change in the way they cut trees. Researchers investigated scenarios and solutions to reduce the negative impacts of climate change and to cope with sea level rise. They looked at how to reduce flooding in Northern Germany and how to deal with reduced water availability and increased salinization in Vietnam and China. The book is filled with many inspiring insights and success stories like these. All have emerged during the seven years of the research programme.

In a nutshell, this book is about scientific research which makes sense in the field. It proves that sustainable intensification of our land use is possible if done right. It can serve multiple purposes from raising and stabilising yields, to securing ecosystems and ensuring the transformation of degrading land into a vibrant and productive natural resource.

Despite all the efforts made in the past decades, land degradation is still one of the most serious problems facing society and disproportionately affecting the poorest on our planet. This book demonstrates ways how research can make a difference. Involving researchers and especially students strengthens the capacity of land users, planners and decision makers to address the complexity of sustainable land management and its current and future challenges at landscape and watershed level. Research and capacity building in sustainable land management is an investment for the wellbeing of the next generation.



Monique Barbut
Executive Secretary
United Nations Convention to Combat Desertification (UNCCD)

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Preface

Much knowledge on sustainable land management is available in the worlds of science and practice. It is just not clear where to look for it, how to ask for it, and what really is relevant to the many interrelated challenges of land management. This book illustrates options to fill some of those gaps.

Land is our natural heritage. It is much more than a commodity. We humans depend on land and its soils, water and vegetation to sustain our lives. The production of healthy food, provision of shelter, a place for recreation, in fact our whole lives depend on land. Yet we still know so very little about it. And we do not use land and its soils sustainably. Arable land worldwide is lost at an alarming scale and speed, presently - due to drought and desertification alone - some 12 million ha annually while 1,5 billion people globally are affected by land degradation (UNCCD 2016 and 2013). Part of the problem is that agricultural research often doesn't link up to the questions and needs of those who manage and use land professionally.

This book is meant to put research on sustainable land management into context: the context of those who manage land and its soils, and those who want to conduct or set up research in a way that it is meaningful for land users. It aims to be useful to land management practitioners who wish to incorporate up-to-date research results into their work of planning and budgeting the use of land, of choosing appropriate farming technologies, to those who provide consulting services, set-up research programmes, or run international dialogues on the future of agriculture. It also targets those who intend to conduct research that can support sustainable land management in practice.

Much knowledge about sustainable land management is available in the worlds of science and land management practice. For many it is just not clear where to look for it or who to ask for it. And it is not always obvious what really is relevant for practitioners, planners and decision-makers. This book illustrates some options for how such information and action gaps could be filled. It translates, and puts into context, research that originates from university-based multi-disciplinary backgrounds supported by a large programme on sustainable land management (BMBF-SLM 2016). It shows that there are many possibilities of linking up research to land management practice. And vice versa: it demonstrates how knowledge from land management practice can be brought into a meaningful discourse with scientists.

This effort of contextualization is based on more than 20 years of experience of the WOCAT network (World Overview of Conservation Approaches & Technologies - www.wocat.net). WOCAT was started to provide evidence-based decision-support for professional land users. By documenting and making available independent research, WOCAT contributes an important element: implementation-oriented knowledge that is based on concrete practice. It can thus be of immense use to those who are confronted with similar land management challenges - such as drought, loss of fertile soils, inadequate irrigation, or alternatives to chemical fertilizers.

There is a long-standing debate concerning the role and future of agriculture in times of a still growing world population, and increasing demand for food. This debate is usually polarised between intensification of land use, with the mixed merits of industrialised agriculture - and expanding farming activities into forests, wetlands, hillsides and pastures.

This book explores a possible alternative:
Routes for 'sustainable intensification'. Those are options to produce higher and more reliable yields with improvements in managing available land resources while respecting, and making better use, of local and regional economic, socio-cultural and environmental conditions.

To be able to discover this alternative, the interrelationship and interdependence of factors such as soil quality, water availability, weather and climate change, biodiversity losses (or gains), as well as socio-cultural factors such as traditional values and taboos, or land use rights all have to be carefully looked into. It is these interrelated factors that are at the centre also of modelling and scenario development through the science underpinning the results of the book. This nexus perspective is difficult, time-consuming, sometimes counter-intuitive and often irritating. But it is necessary to make scientific observations and analysis more useful to sustainable land management practice. And it is a necessary perspective for land managers to be able to explain to scientists what really is at the core of their urgent challenges.

With this focus on the practice of land management the book contributes to filling an important gap: there are not many publications that discuss sustainable intensification while considering, especially, larger scales and interrelated factors in the nexus perspective. Over a period of seven years with the participation of some 100 universities and land research institutes, models and scenarios have been run, and an intensive discourse between scientists and land managers has taken place.

Above all, it has become a stimulating discussion demonstrating alternative routes in a great variety of landscapes and land use types. When compiling and documenting results and experiences we were taken on a trip full of surprises and searches for new options - but also full of remaining challenges.

We invite our readers to take part in this journey and gratefully invite corrections, critique, and additional discussion - in the field, at conferences and meetings, or in virtual space.

Bern, Hamburg, Wuppertal - October 2016

Hanspeter Liniger, Rima Mekdaschi Studer, Peter Moll and Ute Zander

Introduction

Background

This book synthesizes the results of research into sustainable land management (SLM) conducted in some 100 university-based or affiliated institutes and their partners. The background is a research programme on sustainable land management. It ran between 2010 and 2016, and was funded by the German Federal Ministry of Education and Research (BMBF). With more than 600 scientists involved, the BMBF-SLM[1] research programme was the largest funding efforts related to SLM in Germany, and one of the largest worldwide in the last decades. Scientists from many disciplines - natural as well as social sciences and the humanities - and practitioners in the regions worked together in inter- and transdisciplinary projects. The overall focus was on the interactions and interdependencies between land management and climate change, as well as between land management and ecosystem function/ services (ESF/S). Part of the motivation to initiate this programme was to integrate the formerly isolated research fields of climate change, water and biodiversity. In land management, these topics and related challenges all come together.

Besides the scientific research objectives, the programme aimed to contribute to the identification of potential practical solutions to land management challenges. It aimed at developing fresh perspectives on more responsible and sustainable use of scarce land resources in the study regions. And it showed that there are some common denominators across the globe when dealing with challenges due to water scarcity, loss of soil organic matter, climatic change, and loss of biodiversity.

Twelve regional projects spread over four continents[2] have analysed complex interactions between land use, globalization, climate change, loss of biodiversity, population growth and urbanization. The focus was on regions that are disadvantaged as a result of change. These changes include loss of soil fertility, deforestation and erosion, rising sea levels, but also the migration of young people away from rural regions, and increasing urban sprawl.

The backbone of research in most of the associated projects was natural science and modelling – together with scenario building. It is rare to attempt to pull out conclusions of value for land management practice from such research: this makes it all the more valuable. What often can only be observed in a very small study plot and a limited time-frame can - with the help of computer-based models and scenarios - be 'thought further into the future' and be compared with data from other sources.

Based on their research results, the scientists involved developed implementation-oriented strategies and recommendations. And they discussed them with multiple stakeholders: representatives from associations and local initiatives, indigenous people, local/ regional/ national government representatives and their agencies, private enterprises/ business representatives, as well as many individual land users and land owners.

The BMBF call for the SLM research programme asked for 'cross-disciplinary integration and transdisciplinary research' producing knowledge that could be implemented by the people in the respective regions. Therefore, those implementers needed to be involved in the research process itself. Within this book we use the term 'implementation-oriented' to indicate the purpose of the research projects to contribute to SLM on the ground. The overall target of implementation-oriented research on sustainable land management was to produce strategic knowledge within changing contexts of the soil, vegetation, water and climate nexus.[3]

The foundation of this kind of research in Germany is the large umbrella programme FONA (Research for Sustainable Development)[4]. Research conducted under this umbrella is expected to contribute to sustainable development. Therefore regions, mostly sub-national, in two cases international, were the chosen level of scale: land is managed at local and regional, sometimes national levels. It is this real world background that enabled implementation-oriented SLM research to be conducted within 12 regions worldwide: each with their specific problem context[5] (see Annex).

Process and character

The book is based on the results of a kick-off workshop and three synthesis and writing workshops that took place with representatives from the 12 regional projects during 2015 and the first half of 2016. After several feedback loops, the structure for a synthesis of practice-oriented results was developed for projects in such different contexts as Africa, Brazil, China, Germany, Russia, and Southeast Asia.

In these synthesis or writing workshops 'challenges' and 'opportunities' for possible solutions to practice-relevant land use and land management problems were discussed. While it was less difficult for the participating scientists to describe the many challenges and problems involved, the focus on opportunities and possible solutions to these problems was not easy at all. This is not surprising. Science often focuses on 'problems' and WHAT questions (what is the problem? what is the topic here?). When it comes to HOW questions and steps towards possible solutions, that is when methods and tools and strategies for possible implementation are needed: things get more difficult for the usual tool box of research. This was obvious, also, in our meetings. We tried to deal with this by repeatedly discussing 'How' questions and aspects. But the tried and tested WOCAT method for assessing and describing Technologies and Approaches (see Part 2) was very useful in this respect – WOCAT having had more than 20 years of experience in documenting and analysing SLM.

Another word of caution: the book has a special character. It is not a scientific publication or a textbook. It does not attempt to contribute foremost to the scientific discourses about specific topics.

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[1] http://nachhaltiges-landmanagement.de/en/home and http://modul-a.nachhaltiges-landmanagement.de/en/modul-a
[2] See Annex and http://modul-a.nachhaltiges-landmanagement.de/en/projects/
[3] This nexus will be further explained and illustrated with many examples especially in chapters 1+2
[4] http://www.fona.de/en/index.php
[5] http://nachhaltiges-landmanagement.de/en/projects/

In particular, it does not attempt to be exhaustive on topics such as land and/or water management in the respective regions. But the book is an extensive effort to pull out practice- and implementation-oriented results from a large research programme. Topics, or rather challenges, such as 'climate change mitigation' and '(loss of / changing) biodiversity' have been chosen to sensibly bring together, and show to the reader, interconnections among practical SLM experiences and related research results; and to make it possible for the reader to see these interconnections. The many examples referred to in Part 1, as well as the more detailed case studies from Part 2, are illustrations of such interconnections.

Altogether the book presents selected results from twelve regional projects to illustrate what research can do in close cooperation with land management practitioners in the complex context of SLM. It presents tools both for SLM practice and for implementation-oriented research and it shows how such cooperation can work.

Context

Within the international political context, the BMBF-SLM programme relates to the three Rio Conventions: UNCCD[6], UNFCCC[7], and UNCBD[8]. The UNCCD zero net land degradation target (also called land degradation neutrality - LDN) is one of the core foci. Taking into account interactions with the central topics of the other two conventions – climate change and biodiversity/ ecosystems – options for land management that contribute to this target have been developed and analysed.

More recently those topics have been integrated into the Sustainable Development Goals (SDGs)[9] and the UN 2030 agenda.
SLM is most relevant to:
SDG 2: Zero Hunger,
SDG 6: Clean Water and Sanitation,
SDG 13: Climate Action,
SDG 15: Life on Land,
SDG 11: Sustainable Cities and Communities, and
SDG 12: Responsible Consumption and Production.

Nearly every goal has an interrelationship with SLM at least at the level of the targets: for example in target 1.4 the importance of 'access to basic services, ownership and control over land and other forms of property, inheritance, natural resources' is stressed. This illustrates the interconnectedness of land with many other aspects of our lives.

Within the international scientific discourse, the results of the BMBF-SLM programme contribute to two major on-going and interlinked discussions:

- Is there a need for expansion of agricultural land to achieve food security?
- How to best find a compromise between agricultural production and ecosystem preservation - through 'land sparing' or 'land sharing'?

Or, in other words: is it better to intensify agriculture on productive land to spare other (natural or semi-natural) areas from expansion of farming? Or should we strive to better integrate ecosystem preservation in existing production systems?

The first question was answered within the global modelling and scenario assessments carried out in the coordination project GLUES[10]. Global modelling of yield gaps based on biomass production potentials show that future demand for food can most likely be fulfilled without cropland expansion (Mauser et al 2015). This is a major scientific finding from the programme. Research on this finding is continuing in the participating institutions.

However this finding requires land management strategies that are not solely focused on maximizing yields – but on sustainability too. In this context, the book provides practice examples for 'sustainable intensification' that show the application of land management measures for increasing yields without depleting ecosystems, the latter being the basis for life on earth while fundamentally supporting all human production systems (see Chapter 1). It provides examples of extensification of land use and land management, and their benefits and trade-offs. And it shows how ecosystem preservation can be integrated within productive land through corridors and structural landscape elements, and by building up ecosystem function within existing productive land (land sparing and sharing - see Chapters 1-4).

Integrated and implementation-oriented

Land management and land use involve highly complex challenges. When it is, for example, high quality products from agriculture that humans want, we need to take into account all framework conditions: the quality of the available soil and its organic composition; the availability, quality and reliability of water supply; the climatic conditions and indeed related changes; the world market and its great variations - as well as regional economic developments; cultural and socio-political factors enhancing or compromising human capacities and possible success; to name just a few.

[6] UN Convention to Combat Desertification http://www.unccd.int/en/Pages/default.aspx
[7] Framework Convention on Climate Change http://newsroom.unfccc.int
[8] Convention on Biological Diversity https://www.cbd.int
[9] https://sustainabledevelopment.un.org/sdgs
[10] http://modul-a.nachhaltiges-landmanagement.de/en/scientific-coordination-glues

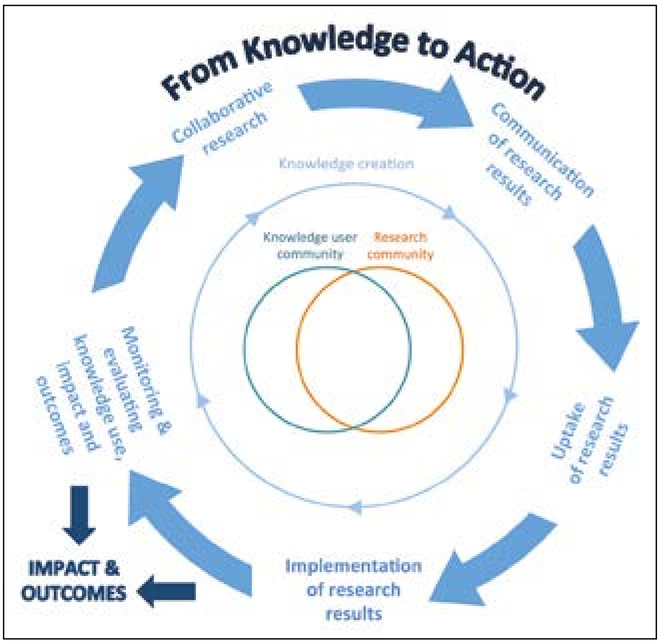
This complexity is mirrored in the research on land management. It requires the involvement of many disciplines from natural and social science and the humanities. Land management and agricultural research results in thousands of academic publications every year.[11] But such papers are not written for farmers. They are written by scientists for their peers - and their own personal advancement. The hands-on practices of land users and managers are seldom the focus: in this respect the WOCAT[12] network and programme is an exception. Implementation-oriented research can still fill an enormous gap. It starts from the questions and knowledge the farmers/ land users and their advisors have. It reaches out to them by involving them – ideally – from the very beginning.

For example: what could an extension worker expect from research focussing on the management of peatlands and humus rich steppe? What kind of results could he/she expect from a research project with such a focus? And consequently, what kind of questions could he/she ask the modellers, natural scientists, and social scientists? By providing examples of more sustainable management of steppe soils, the book indicates a possible entry point to these questions: it was possible to extract from the various models and – in this case – mostly natural science based research, some practice-oriented results concerning no-tillage and direct seeding under conservation agriculture systems. No-tillage farming, from the research results of the supporting research projects, is a possible alternative. It could, in the long run - especially when combined with crop rotation and precision application of herbicides - contribute to more sustainable harvests and control of land degradation. The results from research reflect pros and cons of this alternative and are thereby essential for those who need to make decisions related to this system of production.

Part 2 of this book contains 30 examples from practice. They should be understood like this: to arrive at the cases it needed translation and contextualization of research that did initially not ask practice- or implementation-oriented questions. But the existence of them shows that it is possible to analyse and synthesize SLM research and arrive at good land management practice. To do so, the WOCAT methodology was confirmed to be a very appropriate and useful tool.

Transformative research

In its 2011 flagship report 'World in transition – A social contract for sustainability' the German Advisory Council on Global Change (WBGU) coined the term 'transformative research', describing a kind of 'research that actively advances the transformation' (WGBU 2011). The WBGU distinguishes 'transformative research' from 'transformation research' meaning research on and about transformations. Here an important difference needs to be noted: Whereas 'transformation research' concerns *knowledge about* (about basic facts of e.g. soil composition, water quality, weather conditions - answering 'what is?' questions), 'transformative research' is concerned about and working towards *knowledge for* (for meaningful change, adjustments of present routines, innovating existing technologies, etc.). These different kinds of knowledge are particularly important when it comes to questions about possible practical implementations of research. Both kinds are useful and much needed. But *knowledge for* often plays a greater role in cooperation with practitioners of land management. They want to know what needs to be done and how change can be managed.



From knowledge to action. (http://heicresearch.com/wp-content/uploads/2014/01/KM_illustration_draft6.jpg)

Much of this debate originates from a discussion about 'from knowledge to action'; especially in the area of research for sustainable development. Originally, the concept still meant a one-way route: scientists developed knowledge that in the end of a research project needed to be diffused and transferred to possible users of this knowledge. 'Do your science well and good will follow' was still somewhere behind this rather naïve approach - when real world uptake of action really was intended.

This has evolved since into more ambitious ways of designing and doing research that is intended to be of use in and for practice. From knowledge to action is seen increasingly as a kind of 'mobilization process' in which the 'knowledge-user community' needs to be involved as early and as much as possible:

Different kinds of knowledge

What is often missing in these conceptualizations is the understanding that there are actually different kinds of knowledge. Science is capable of developing particular kinds of knowledge, such as knowledge about basic facts, about causes and effects, and about systems and their interaction. People active in land management hold other kinds of knowledge: local knowledge based on practical experience, knowledge about checks and balances, and about steps and strategies of real life implementation. And, for example, indigenous people often offer astounding insights into long-term effects of individual measures - or may be able to relate natural phenomena to spiritual experiences. In our view all these kinds of knowledge are valuable: there is no hierarchy. All these types of knowledge are needed for meaningful change. The real challenge behind this is to make room for all of them and to make them communicate and – ideally – become synergetic.

[11] see for example http://www.omicsonline.org/agri-food-aqua-journals.php?gclid=CPbVqJDQj88CFYQy0wodbdwLYg
[12] www.WOCAT.net

A currently used term for this challenge is that of 'co-production of knowledge' or in a broader focus: co-design (of research), co-production (of knowledge and solutions), co-delivery (of results), sometimes complemented by co-interpretation (of results). Here we all are just at the beginning. The book gives some examples of steps in this direction.

Target groups

The book is intended to be of use for three main target groups:

- Land management practitioners: for example farmers, extension services, agricultural advisors and consultants, regional water authorities or other land policy/ land management institutions.
- International organisations: UN bodies and farming experts working in them; for example within UNCCD, GEF, FAO, IFAD, the World Bank, the European Commission and its agricultural programmes, as well as private foundations and organisations focussing on agricultural innovations, improvements and reforms.
- Scientists and funders/ designers of research programmes: those who are facing the challenges of implementation-oriented research, of involving stakeholders, of coordinating multi-, inter- and/or transdisciplinary research; particularly in the area of sustainable land management.

We hope that the BMBF-SLM programme's experience can be useful to them. And we hope that we can encourage others to make use of the WOCAT method for documenting and sharing results, evaluating practice-related work, and pulling out lessons learned. Beyond the interested reader from the general public, it is particularly intended for those target groups listed above that the book has synthesized the implementation-oriented research of more than 600 scientists who worked in this BMBF-SLM programme for seven years in nine countries and twelve regions.

How to read the book

Most readers will flip through this book, stop here and there, look at photos, graphs and individual cases. Whatever is closest to their own work, or to their particular interest at this moment, will capture their attention and demand more careful reading. The book is meant to be like that. It invites selective reading. It is not meant as a textbook or scientific publication that needs reading from beginning to end. But it could be read like that too. The light that is shed on the basic question 'what is, and how to do, sustainable land management with the support of implementation-oriented research?' builds up gradually through Chapters 1 to 7.

Overview

Part 1 summarizes the implementation-oriented results of the twelve research projects. It contains six chapters that provide insights into challenges of, and possible solutions to, sustainable land management. Here land management efforts are distinguished on a systemic level: (1) *local land management* with basically one land use system or one system clearly dominating (e.g. cropland management for the production of wheat and other cereals), and (2) *landscape management with multiple, interrelated and interdependent land use systems* (e.g. irrigated agriculture competing for water with hydropower and nearby urban development).

Chapters 1–4 synthesize and reflect on the overall results from research and implementation-oriented work of the 12 projects, with many examples of sustainable land management practices.

Whereas these four initial chapters cover many specific options towards more sustainable land management practice (what can be done? what kind of challenges? what kind of possible solutions?) the following three chapters, chapters 5–7, summarize and illustrate methodologies and tools for better communication between research and practice, explore the role of research while highlighting methods like modelling and scenarios that help to inform better SLM decisions, as well as pull out overall lessons learned.

Part 1

Chapter 1: Local land management – the soil, vegetation, water and climate nexus
Chapter 2: Landscape management – adapting to climate change
Chapter 3: Mitigating climate change
Chapter 4: Protecting biodiversity and ecosystems
Chapter 5: Bridging gaps between research and practice
Chapter 6: The contribution of research
Chapter 7: Conclusions and key messages.

Key points in the text are highlighted in colour.

Part 2

The case studies in Part 2 of the book then provide examples of what can be done. There are already many examples in Part 1. But here, in Part 2 thirty selected case studies of sustainable land management practice are described in more detail by making use of the WOCAT format that ensures better clarification, easier comparison and simpler application.

The case studies are presented in alphabetical order according to country/ region and project name to make it easier to find the topics and countries the reader is particularly interested in. They can also be found online in the WOCAT database[13] together with related videos for downloading[14].

The Annex

The Annex provides an overview of the BMBF-SLM research programme and its 12 individual projects are described in more detail. Links for following up some of the routes for sustainable land management practice are given. And it contains the references for all chapters, including further supporting literature literature, a glossary of key terms used in the book and a list of abbreviations.

[13] see: https://www.wocat.net/en/knowledge-base.html, look for either ‚Technologies' or ‚Approaches'
[14] see: https://www.wocat.net/en/knowledge-base/slm-videos.html


Batad, Philippines, André Künzelmann/ UFZ

Part 1

PART 1

Research evidence in support of sustainable land management

Namibia, Ibo Zimmermann

Introduction

Land management analysed in this book ranges from single smallholder plots with one land use system, to large-scale land use under mixed systems, onto highly complex landscape or watershed scales with combined, integrated and interdependent land use systems. Land management at the local level deals with important single land management systems at small or large-scale, and a focus on their on-site impacts. Land management at the landscape level combines local land management with different land uses, fulfilling multiple claims and functions, with impacts on the whole system. This includes interactions up- and downhill on a slope from a hilltop to the valley, up- and downstream within a watershed, or 'up'- and 'downwind' within a region affected by wind (and therefore dust storms).

Whether at the local or at the landscape level, multiple claims are made on the land and its resources: soil, water, vegetation and fauna. There are ecosystem functions and the various services that are derived from the land, which are also affected by land use. Claims on the land may lead to complementarities and even synergies – but often there is competition. There can be multiple trade-offs and balances to be found between food security, combatting land degradation, reducing water conflicts, reducing disaster risks, adaption to climate change, and mitigating climate change, to maintaining biodiversity and natural habitats.

Many reports and assessments describe and analyse challenges and threats related to land management due to land degradation, such as the physical and chemical degradation of soils, the loss of valuable vegetation and its diversity, dwindling water resources and reduction in its quality. The impacts of 'good' or 'bad' land management have implications at all levels: local and regional, as well as global.

In the following chapters, the aim is to focus on practical solutions and the contribution of research – and especially implementation-oriented research – towards improving land management at the local and landscape level, dealing with the complexity of land and its management, identifying sustainable practices, and promoting good governance for further adoption and spread of sustainable land management practices. Chapter 1 focusses on land management at the local level, whereas Chapter 2 integrates local land management into the landscape or watershed level, showing interactions and interdependencies of local interventions and regional impacts. Chapters 3 and 4 highlight land management in view of global claims regarding climate change mitigation and biodiversity. Chapter 5 addresses lessons learnt for approaches to implement sustainable land management practices and how to bridge the gap between research and practice. Finally, Chapter 6 reviews the unique contribution that research can make in supporting evidence based decision making and upscaling sustainable land management.

CHAPTER 1

Local land management – the soil, vegetation, water and climate nexus

Western Siberia, Immo Kaempf

Introduction

At the local level, for each land use system, the management of soil, vegetation and water under given climatic conditions has to fulfil different needs and services. Land management needs to deal with the often dwindling resources of fertile soil, available water, biodiversity and natural habitats. Their interactions must be taken into account also. This poses a significant challenge for land users to adapt to different claims on the land, and changing and often growing demands and needs – as well as altering natural and human environments. Climate change adds an extra layer of complexity and threats on land management.

The following management issues are addressed at the local level:
- Integrated management of agricultural production systems, both at large-, medium- and small-scale
- Managing irrigation and fertilization
- Eco-engineering
- Adapted livestock and grazing management
- Integrated management of natural and semi-natural systems with a focus on non-timber forest products

Addressing improved land management at the local level is a question of maximising opportunities as well as dealing with trade-offs. Traditions need to be acknowledged – but the concrete contributions of research also. The challenges and the basic principles of good land management at the local level are elaborated at the end of this chapter.

1.1 Integrated management of agricultural production systems

Agricultural production has been, and will remain, a key element of land management. This chapter focusses on strategies that combine different measures – for example no-till, crop rotation, intercropping, pest management, agroforestry and soil enrichment. It illustrates the multiple benefits of these for soil fertility, plant productivity, erosion prevention, and soil water holding capacity, as well as interactions with biodiversity, climate change adaptation and climate change mitigation. These strategies with their different components have been tested and proven in very different contexts: large-scale production systems in Brazil, China and Russia as well as small-scale production systems in Madagascar and Namibia.

1.1.1 Large-scale agricultural systems

In general, the large-scale industrialisation of agriculture in North and South America, Australia and Europe and the 'Green Revolution' in Asia have led to impressive successes in increasing productivity over the past fifty years. Large-scale intensive agricultural production systems rely usually on high inputs of plant materials, machinery, inorganic fertilizer and pesticides. The intensive use of these inputs, however, endangers sustained fertility of soils and their ability to maintain yields. Along with standard economic theory, there is a law of diminishing returns with respect to inputs: and at some point extra inputs no longer improve production or other services. Indeed they can harm the natural resources. Intensive

Figure 1.1: Aerial photo of typical appearance of the Kulunda steppe, Russia. (Manfred Frühauf)

Figure 1.2: Effects of wind erosion with the loss of topsoil, soil organic matter and nutrients in the Kulunda steppe, Russia. (Tobias Meinel)

large-scale farming practices may lead to accelerated land degradation, such as soil erosion, salinization, a decrease in vegetation cover and depletion of water resources. Irrigation practices are increasingly threatened by salinization. At this point, land users are particularly challenged to adopt 'sustainable' practices. Implementing single measures such as no-tillage usually comes with trade-offs; for example an increase in weeds and consequently the need for higher application of herbicides. Such disadvantages illustrate the requirement to change the whole production system to a more sustainable one that is tailored to reducing artificial inputs and – where possible – makes better use of natural ecosystem services.

The contribution of research to improving large-scale agricultural production systems are presented and illustrated from:

- Russia: multiple benefits from a combination of no-till and minimum tillage with crop rotation and precision farming
- Brazil: preventing erosion by water with no-tillage and earth bunds
- Southern China: preventing soil erosion by water through a change in weeding practice
- Northern China: preventing soil erosion by crop rotation, intercropping and using salt tolerant plants on abandoned saline fields

Wheat production in the KULUNDA steppe, Altai Region, western Siberia, Russia

Kulunda steppe the alternative bread basket

context: Since the collapse of the former Soviet Union it can be observed that the Altay Krai Region including the Kulunda steppe is continuously increasing in its importance as a breadbasket for the Russian Federation

problem: soil degradation caused by wind erosion, loss of fertile topsoils, decreased soil organic matter content (loss of water and nutrient holding capacity, carbon sequestration etc.) and decreased aggregate stability. Bare soils lead to unproductive evaporation causing additional water losses exacerbated by climate change

solution: no-till/ minimum tillage for wheat production: less soil disturbance (less mineralization/ oxidation of organic matter, better aggregate stability), better soil cover by crop rotation/ mulching, precision application of herbicides

message: restoring land to agriculture without bringing back the losses of soil organic matter and topsoil needs a new approach: one way of achieving sustainable intensification is through reduced tillage systems combined with direct drilling, rotations and mulching

Figure 1.3: Russian tractor (Kirovets K700A) with an air seeder (direct seeder) 'Condor'. The scheme shows the seeds being placed between the lines of stubble in the wet soil. (photo: Tobias Meinel; illustration: Amazon-Werke)

Figure 1.4: Mulch and residue management and field emergence after direct seeding of spring wheat (left) and oil seed rape (right), in the Kulunda steppe, Russia. (Tobias Meinel)

In the global context, significant increases in wheat yield have been achieved in the last decades. Yet, this has not been the case for the large-scale intensive farming in the Kulunda steppe where agricultural yields have been fluctuating strongly due to difficult climatic conditions and drought, and as a result of wind erosion leading to decreased topsoil depth, lower soil organic matter content, less sequestered carbon and reduced soil fertility. In addition, regular 'black fallow' in crop rotation leads to uncovered soil with an increased risk of erosion and lower farmer income. Today some 50% of these lands are degraded (Figures 1.1 and 1.2).

No-till, crop rotation, precision herbicide application

To prevent another dust bowl in the Russian Kulunda steppe, the sustainable land management strategies, no-till and minimum tillage (see Technology 'Minimum tillage' page 251 and Video) were tested as alternative cultivation methods to conventional deep tillage (Figure 1.3).

The successful implementation of no-till and minimum-tillage when combined with mulching and crop rotation requires adaption of the whole cropping system. No-till (also called zero tillage or direct drilling/ seeding) is a way of growing crops from year to year without disturbing the soil through tillage/ use of the plough. Minimum tillage is a method that does not turn the soil over, but only allows the minimum soil disturbance necessary for successful crop production: it is used where no-till is not possible because of certain soil conditions. Leaving crop residues on the surface and using crop rotation based on crops that differ in length of growing period and sequence within the rotation, ensures a high and continuous degree of soil coverage. This leads to the suppression of weeds in the no-till or minimum tillage systems. Furthermore, shading of the soil reduces non-productive evaporation. The frequent change of crops has a positive effect on soil structure, fertility and pest/ disease control. These practices are more labour and cost-efficient, leading to increased farm income.

In a good crop rotation scheme, instead of black fallow, rape seed and nitrogen-fixing peas are grown, leading to balanced use and provision of nutrients, a high degree of leaf coverage and soil structure improvement (Figure 1.4).

One of the main objections to no-till/ minimum tillage practices is an increase in weeds which in turn usually leads to an increase in herbicide use. This trade-off can be avoided by using infra-red detection technologies with high precision – applying herbicides only where weeds are growing (Figure 1.5).

Figure 1.5: Spreader UX 5000 with the weed detection system Amaspot. The scheme shows the Amaspot system: an infrared sensor detects green/ growing weed and initiates, and stops spraying when passing over the field, in the Kulunda steppe, Russia. (photo: Lars Grunwald; illustration: Amazon-Werke)

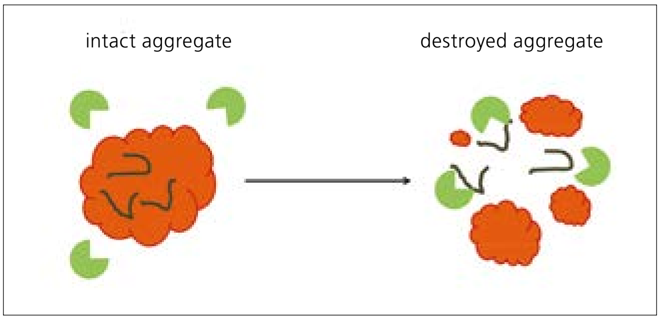


Figure 1.6: Intact soil aggregates (orange) bind or 'encase' organic substance (black) and protect it from mineralization and decomposition by micro-organisms (green). Destruction of aggregates makes organic substance accessible to micro-organisms for decomposition. (Norbert Bischoff)

Aggregate stability and soil organic carbon

Reduced soil tillage reduces the depth of soil disturbance and thus leads to higher soil aggregate stability (aggregates are destroyed by ploughing). Higher aggregate stability protects soil organic matter from decomposition and mineralization (Figure 1.6). Changes in aggregate stability may serve as an early indicator of recovery or degradation of soils. Aggregate stability is thus an indicator of organic matter content, biological activity, and nutrient cycling in soils (www.soilquality.org/).

Degradation effects, due to conventional ploughing practices, can be observed in the Kulunda steppe. The reduced soil aggregate stability under intensive soil cultivation has led to a higher risk of wind erosion and thus losses of soil organic carbon (SOC). Silt and clay elements in the topsoil are blown away from the field, and sand is left on the surface (Figure 1.7a and 1.7b).

The interconnection between aggregate stability and SOC content can be seen in the correlation between the two: in the different types of steppe (forest, natural, dry) the more stable the aggregates, the higher the SOC (Figure 1.8).

Losses of soil organic carbon (SOC) content through conversion of grassland in different types of steppe (forest, natural, dry) to cultivated land with deep tillage are significant. With the loss of SOC, fertility of those croplands is affected negatively, particularly within the topsoil (Figure 1.9). In the typical (natural) steppe, conversion from grassland to conventionally cultivated cropland means up to 41% loss of SOC in the upper 10 cm of soil, 35% in the top 25 cm, and also losses down to 60 cm.

In the face of future climate change with a predicted drier climate in the semi-arid steppes of Siberia, SOC stocks will decrease within the conventionally cultivated steppes due to reduced biomass input under dry conditions.

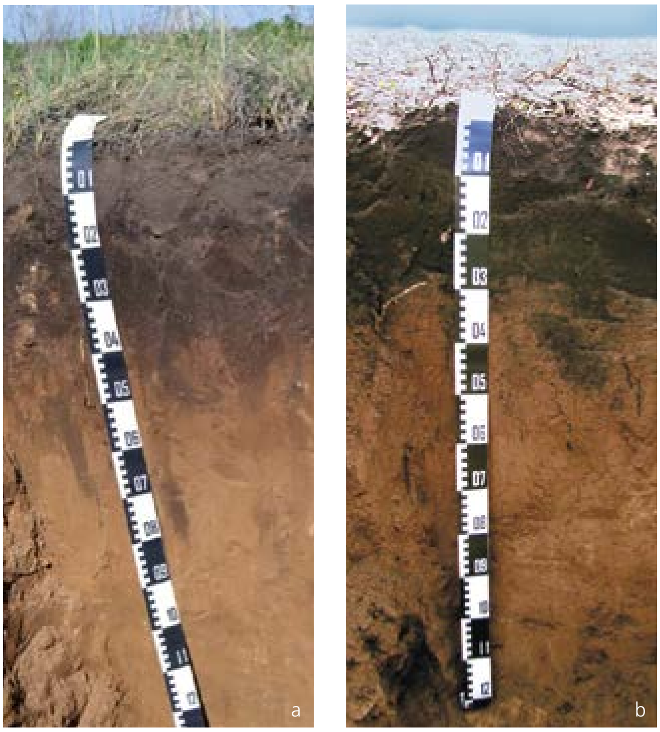


Figure 1.7a: Typically developed Kastanozem soil in the Kulunda region under natural steppe (fallow shelterbelt) with dense vegetation cover, a strongly developed root system, dark humus and a nutrient rich topsoil (A- horizon). A transitional layer (A-B horizon) at a depth of 35-50 cm between the humus rich topsoil and the mineral subsoil is created by microorganisms, worms and mammals – and cracking. (Andreas Eisold)

Figure 1.7b: Typical soil profile of intensively tilled cropland in the Kulunda dry steppe. The protective vegetation cover is missing and the soil and its natural aggregates are destroyed by tillage and exposed to wind erosion. The upper 10 cm of topsoil is degraded, the organic material is decomposed and the fine soil particles are blown away leaving a sand layer behind. Due to the loss of topsoil, the ploughing reaches below the transitional layer, and mixes mineral subsoil with the organic top soil and creates a sharp plough horizon. The result is a degraded soil with decreased water storage and lower nutrient holding capacity. (Patrick Illiger)

To measure the effects of changing the agricultural practice from ploughing to no-till or minimum tillage, SOC was compared at different test sites. The SOC loss (in percentage) due to the different agricultural practices are shown in Figure 1.10. The conventional method of ploughing leads to severe carbon losses – of almost 50% in the topsoil compared with undisturbed grasslands, while lower loss rates, up to a maximum of 30%, were found for no-till or minimum tillage measures.

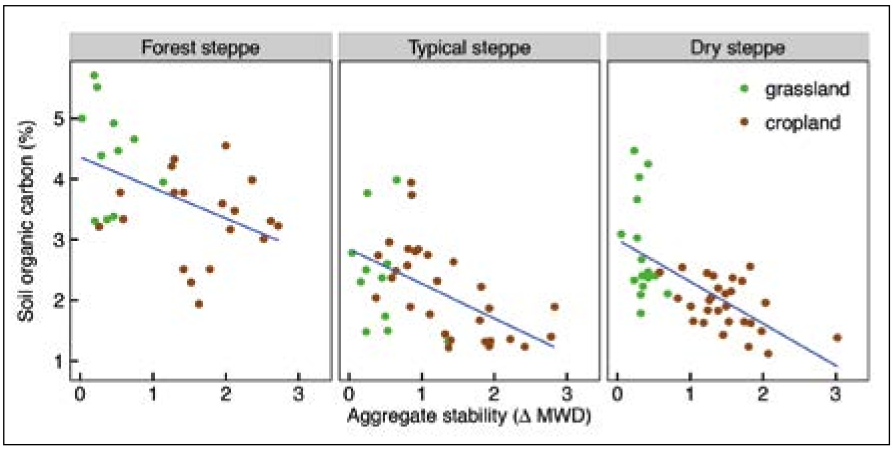


Figure 1.8: Comparing SOC content in percent to aggregate stability of different biomass (Forest, Typical and Dry steppe) and two land uses grassland and cropland under conventional tillage. A low value of aggregate stability (Mean Weight Diameter, MWD) equals high stability, increasing values of MWD equals decreasing stability. (Norbert Bischoff)

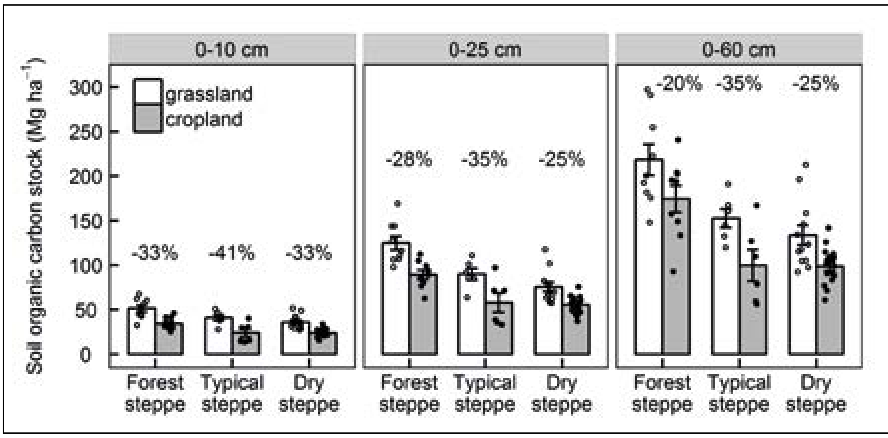


Figure 1.9: Soil organic carbon stocks (SOC in Mg ha-1) for cropland and grassland for 0-10 cm, 0-25 cm and 0-60 cm in different biomes of the Kulunda steppe. Values are given as arithmetic mean (± standard error of the mean) and points show individual measurements. Percent shows the decrease in SOC due to conversion from grassland to conventionally cultivated cropland. (Norbert Bischoff)

Effects on soil cover and soil moisture

In dry steppe, water is the limiting factor for rainfed crop production. Erratic and limited precipitation combined with unproductive evaporation from the soil surface – as observed in the dry steppe of western Siberia – and the projected rising temperature in this region will serve to increase evaporation losses. As crop production is the basis for livelihoods in these regions, the challenge is to sustain this agricultural system despite increasing climatic changes and extremes, like droughts in the south of the region in the Kulunda steppe and in the Tyumen steppe (see page 24).

Experiments in the Kulunda steppe measuring the water balance of different production systems (using lysimeters) proved that unproductive water losses by evaporation and runoff could be reduced by:

- leaving organic substance (living or dead) on the surface (mulching and crop residue management)
- minimizing the period when soil is bare (by applying crop rotation)
- reducing soil disturbance as much as possible (with no-till or minimum tillage)

Compared to the cropland production systems, the soils under natural steppe vegetation cover were able to hold much more water. Thus, the traditional land uses which were practiced for centuries (especially livestock-based nomadism) have the least losses of water, and the highest biomass productivity.

Costs and performance of no-till/ minimum tillage farming

A significant reason for the introduction of no-till or minimum tillage is that they provide higher economic benefits. Conventional deep ploughing incurs higher fuel and wage costs (FAO 2012a). On the other hand, the adapted no-till system with direct seeding system requires investment in modern technology, and also incurs costs in terms of fertilizers, pesticides and herbicides. Nevertheless, profit margins were still higher in total than those of the conventional cultivation system (Table 1.1). The potential yield increase of no-till and minimum tillage during the first years was assessed to be about 25% compared to the conventional practice. The newly introduced methods meant increased application of pesticides and herbicides, which were rated as negative effects. Yet other impacts were positive compared to the conventional system. Reliable data, however, can only be generated after long-term monitoring of the test sites (10 years minimum). Between no-till and minimum tillage, no significant differences regarding the profits were detected.

These adapted cultivation systems are considerably more profitable than the conventional system. This is mainly due to the high selling prices of oilseed rape and field peas introduced into the crop rotation instead of the conventional black fallow. Nevertheless, the absolute revenue of the conventional system was higher. However, the variable costs of this system were also greater compared to the direct seeding system. The operating costs of the direct seeding system were lower due to the ability to cover large areas quickly with its low tillage intensity. Reduced disturbance of the soil by no-till or minimum tillage combined with direct seeding, the maintenance of crop residue in the field, and crop rotations and species diversity were shown to reduce soil erosion by wind, allow recovery of the soil structure and organic matter, conserve water, and build up nutrient stocks leading to higher yields. Such practices were found to be more labour and cost-efficient leading to increased farm income (Baker and Saxton 2007; Soane et al. 2012).

Figure 1.10: Reduction of soil organic carbon (SOC) depending on the soil cultivation practice and intensity in relation to natural grassland steppe at two test sites in Poluyamki, western Siberia. Sites have been under no-till/ minimum tillage regime for a minimum of 5 years. Grassland soils were treated as natural soils with no human induced carbon changes. Accordingly they were set to zero (0). (Norbert Bischoff)

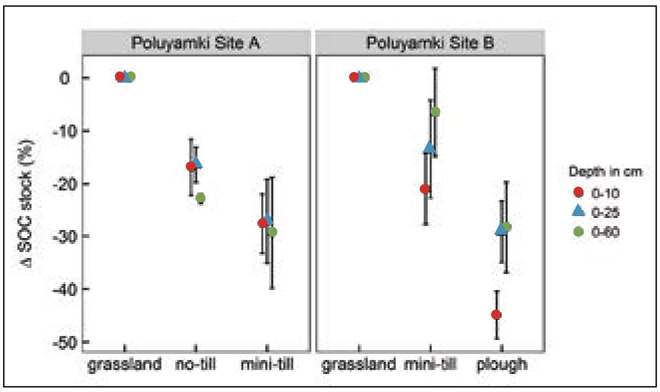


Table 1.1: Costs and benefits of different cropping systems with conventional ploughing, no tillage (No-till) and minimum soil disturbance (Min-till) in the Kulunda steppe. (KULUNDA 2016).

Costs/ inputs: ++ strongly increased; + increased; + neutral; - decreased

Assessment: very positive, positive neutral, negative

	No-till	Min-till	Conventional
Cost			
Seed	±	±	±
Pesticides	+	+	– –
Fertilizer	+	+	– –
Wages	– –	–	+
Diesel fuel	– –	–	+
Maintenance	– –	–	+
Fixed production costs	+	±	–
Benefits			
Revenue	+	++	–

Figure 1.11: No-till seeding (left) and conventional tillage seeding (right) under the field trial, Ishim, Tyumen province, Russia. (Insa Kühling)

Intensification of crop production in the western Siberian forest steppe, Tyumen province, Russia

Abandoned former cropland reclaimed

context: cropland abandonment had a positive effect on reclaiming biodiversity, carbon stocks, and soil fertility

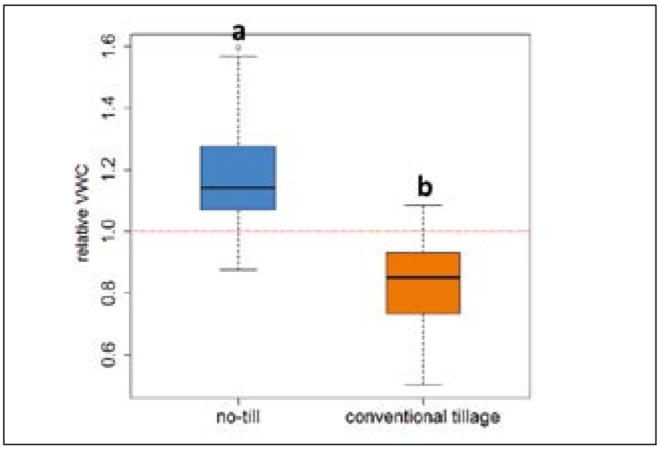
problem: significant trend towards agricultural intensification with increase in inorganic fertilizer application, simplification of crop rotations and a trend to growing more cereal crops

solution: sustainable intensification by no-till, mulching and adapted crop rotation (crops with lower water needs), more efficiency in use of fertilizer and pesticides

message: reclaiming land for production increases income and decreases rural unemployment but also threatens a decrease in biodiversity, carbon stocks and soil fertility unless tillage practices are changed and crop rotation is introduced

The break-up of the Soviet Union in 1991 triggered massive cropland abandonment. Forty-five million hectares of cropland have been abandoned during the transition from a state-controlled to a market-based economy across the former Soviet Union (Schierhorn et al. 2013; Kurganova et al. 2014). However, since around 2003 recovery has started in the agricultural sector, and significant areas of former cropland are now being reclaimed (Kamp 2014; Kamp et al. 2015). The large-scale abandonment of cropland had positive implications for the environment: depleted biodiversity recovered (Kamp et al. 2011), and carbon stocks and soil fertility increased on the abandoned land (Kurganova et al. 2014).

Figure 1.12: Cumulative soil water from seeding to harvest (volumetric water content (VWC)) showing the higher water availability for no-till compared with conventional tillage (n=312) (Insa Kühling unpublished data).



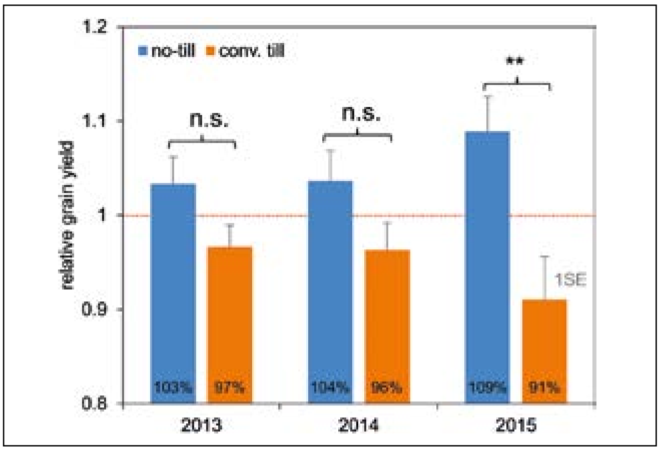
Re-cultivation has led to rural development and decreased rural unemployment (Petrick et al. 2012) but has also resulted in new loss of biodiversity and carbon stocks, as well as decreases in soil fertility.

In Tyumen province, since 2007, there has been a significant trend towards agricultural intensification, with a marked increase in inorganic fertilizer application, a simplification of crop rotations and a trend to growing more cereal crops (Kühling et al. 2016). Furthermore, cropland is managed relatively traditionally in the area, and at low levels of resource use efficiency. Due to the large management units under conventional tillage practices, wind and water erosion result in a loss of humus (soil organic matter), soil fertility, and therefore in production. Climate change is expected to lead to an increase in drought risk in the south of the region.

The main challenges to soil management in the area can be summarized as follows.

1) Increase yields on farmland to offset the need to recultivate more abandoned fields;
2) Maintain or decrease current levels of fertilizer and pesticide use;
3) Maintain soil organic carbon levels on existing and recently reclaimed cropland;
4) Maintain soil fertility in an era of reduced crop rotations and increasing monoculture;
5) Reduce wind and water erosion; and
6) Adapt crop production to climate change (i.e. to a decrease in water availability).

Figure 1.13: Wheat grain yield in a ten hectare field trial for no-till (three different plots one year after adoption of no-till practice) compared to conventional tillage; n.s.: differences not significant, **: differences significant ($p < 0.05$); error bars give standard errors. Relative grain yield: 1 is equal to the average of all treatments (Kühling and Trautz 2016).



In the research project a no-till field trial on 10 ha was set-up. In a randomized block design, two seeding parameters were varied, namely seeding depth and seeding rate (number of wheat seeds/ha). Both options were tested under conventional tillage, and no-till, over three seasons (2013–2015) (Figure 1.11). The parameters soil moisture, plant available soil nitrogen content and grain yield were compared between all possible tillage options (no-till/ till), seeding depth and seeding rate.

While some results varied temporarily over the course of the seasons, clear advantages of no-till over conventional till were recorded. Overall, soil moisture was on average 42% higher on no-till plots compared to conventional-till plots (Figure 1.12). Grain yield was, at 3.4 t/ha, 11.3% higher on no-till plots, and protein yield was 10.6% higher averaged over the three trial years (Figure 1.13). Economic calculations revealed that fuel and labour costs were 73 – 80% lower on no-till plots, compared to plots with conventional tillage. The trial was conducted in a period of rather wet and cool summers, and soil moisture benefits could be even higher in drier years.

As a conclusion, no-till could bring significant advantages in western Siberia. This is especially the case as farmers prepare the land with very powerful machinery, and would not therefore need to invest in bigger tractors. The next steps would be to evaluate adoption of the new technology, and to assess if weed loads are much higher, necessitating an increased use of (expensive) herbicides with undesired environmental side-effects.

Large-scale crop production in Mato Grosso, Brazil

Soil conservation in Mato Grosso, Brazil

context: deforestation of natural vegetation (dry forest), large-scale intensive production of soy beans, corn (maize), and sugar cane

problem: excessive soil erosion by heavy rainfall; rainfall events will increase due to climate change; limited depth of fertile topsoils

solutions: soil conserving production practices such as no-till/ minimum tillage and crop rotation, earth bunds and small dams hinder water flow leading to reduction in soil erosion, improvement of soil fertility, improvement of soil moisture, and more efficient field work

message: there are many known and described options to help introduce sustainable intensification and to control soil erosion, thus negating the need to open new land

The region of Mato Grosso in Brazil belongs to the semi-humid tropics and to the *Cerrado* biome (dry forest) in the centre of the South American continent. Natural vegetation was removed during deforestation some 20-40 year ago, and the land was converted first to pasture and then after some years to large-scale production of soy beans, corn (maize), and sugar cane. After the cutting of the *Cerrado* forests, the natural protection to the soil from heavy rainfall was gone. To prevent excessive soil erosion, farmers adopted soil conserving practices like no-till, while experimenting with a five-year crop rotation scheme where, after maize and soy bean, grass is sown to feed cattle, followed by millet or sorghum and nitrogen fixing legumes (Figure 1.14). After harvesting, the stubble from maize or soy remain on-site. When the planting season starts, the soil is opened by rolling discs pulled by a tractor (Figure 1.15). In one operation, the seeds are directly placed into the soil – which is then compressed with the wheels of the same machine.

Figure 1.14: Sorghum as 'green manure' for soil enrichment; it will not be harvested but ploughed into the soil, Mato Grosso, Brazil. (Stefan Hohnwald)

Figure 1.16: Earth bunds to control runoff in cases of heavy rainfall in the Mato Grosso, Brazil. (Stefan Hohnwald)

With minimum tillage practices, tilling and seeding operations can be implemented quickly and efficiently. Minimum tillage and direct planting in one field operation allows the cultivation of large fields in a short time; this is a great bonus if 'narrow windows' of wet conditions need to be used. The technology has been implemented since approximately 2000 – with an adoption rate of approximately 90%. However, a high standard of tillage tools, tractors (and maintenance) is needed. Since the whole system has changed, farmers need special knowledge in no-till measures – especially in pest management and herbicide application.

To protect against topsoil losses due to heavy tropical rains, one metre high earth bunds are built where runoff occurs on the slightly sloping tablelands (Figure 1.16). Tractors are used to install the bunds. These bunds or terrace banks have to be repaired and improved periodically. As climate models project an increase of heavy rain events in the future, the implementation and maintenance of the bunds will become ever more important.

Figure 1.15: Direct seeding using rolling discs. In one operation, the seeds are directly placed into the opened soil which is compacted afterwards with the wheels of the same machine, Mato Grosso, Brazil. (Stefan Hohnwald)

Figure 1.17: Rubber-based production systems improve livelihoods quickly, within few years, south-west China. (Patrick Grötz)

Rubber plantation in Xishuangbanna, Yunnan Province, south-west China – a biodiversity hotspot

Rubber plantation in south-west China
context: monoculture rubber plantations have been massively increased at the expense of both traditional agricultural areas and forests
problem: loss of biodiversity and C-storage, soil erosion by water, higher runoff through conversion (deforestation) and intensive land use (rubber plantations with clean weeding) with intensive production gives a high economic benefit to the people
solution: mix of intercropping, restricting maximum plantation size, improve weeding practice to leave undergrowth on the slopes: differentiated application of herbicides to ensure undergrowth; possibility of intercropping with endangered species as a biodiversity measure and for additional income
message: where very profitable mono-cropping systems for farmers bring associated problems of loss of biodiversity etc. the best approach is to modify the methods of production with (for example) intercropped indigenous plants – and awareness-raising

Xishuangbanna prefecture in south-west China belongs to one of the world's biodiversity hotspots. Within the last two decades, monoculture rubber plantations have been massively increased at the expense of both traditional agricultural areas and forests. Rapid improvements in wellbeing and livelihoods of smallholder farmers (Figure 1.17) have resulted but to the detriment of the environment – degradation and dramatic declines in biodiversity (Figure 1.18).

Figure 1.19: Considerable erosion in a new rubber plantation intercropped with pineapples. The rubber trees (bright green dots) are planted on terraces while the pineapples have been planted in vertical rows (up and down the slopes) between the terraces, Yunnan province, China. (Gerhard Langenberger)

The possibility of income generation is a strong incentive to the local communities. Recently, since around 2010, rubber plantations have been substituted by even more profitable banana production, causing worse threats to the natural systems due to the high and unselective use of agrochemicals. Often, new rubber plantations, up to 2-3 years old, are intercropped with sun-loving pineapple or maize for income generation. On steep slopes this intercropping gives no protection against soil erosion especially when pineapples are not planted along the contour (Figure 1.19).

Deforestation and biodiversity loss due to rubber cultivation and other monocultures is a problem perceived mostly by outsiders, namely scientists, but also more and more by the Chinese society. Figure 1.20 shows the decline of animal species in rubber plantations compared to natural forests.

Expansion of rubber plantations and its effect on ESS were modelled in order to show different scenarios and consequences of land use change and different land management on ESS and the trade-offs. Through scenario analysis, the benefits and trade-offs of alternative management options were explored – such as a change in the weeding practice that has impacts at the local level (loss of topsoil and water) and at the landscape level (a reduction of water pollution due to less runoff and erosion/ sediment transportation) (Figures 1.21 and 1.22).

Figure 1.18: Decrease in biodiversity as shown by natural forest (left, Thomas Aenis) and rubber forest after 25 years, Yunnan province, China (right, Gerhard Langenberger)

Figure 1.21: Recently cleared mountain slope for the establishment of a new rubber plantation. The onset of erosion is clearly visible – even before the commencement of the rainy season, Yunnan province, China. (Gerhard Langenberger)

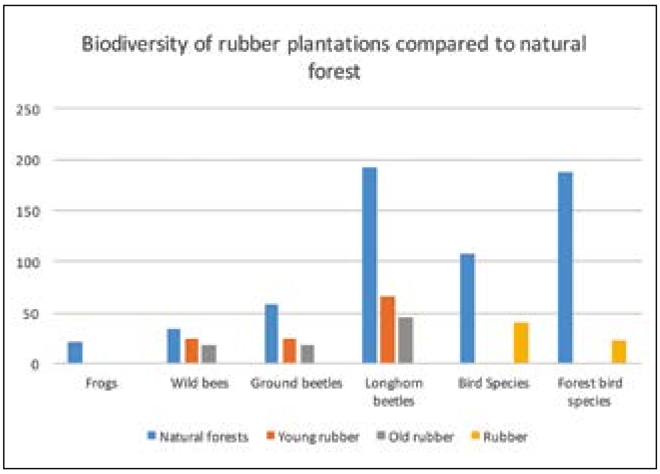


Figure 1.20: The impact of rubber plantations on biodiversity of animal species – a synopsis of different studies. (Gerhard Langenberger based on data from Aratrakorn et al. 2006; Behm et al. 2013; He and Martin 2015; Peh et al. 2006).

There is a strong incentive to improve local incomes by converting natural forest to rubber. However, leaving natural vegetation between the rows of rubber to cover and stabilise the soil would reduce surface erosion and increase biodiversity in rubber plantations. In sloping terrain, the common practice of clean-weeding with herbicides results in bare soils under the trees (Figure 1.23). Rubber plantations are usually managed as monocultures, and farmers tend to clean-weed interspaces and slopes between the rubber rows on the terraces with herbicides (mainly glyphosate). This affects soil

Figure 1.22: Slash and burn: a newly established rubber plantation, Yunnan province, China. (Gerhard Langenberger)

structure since the root systems of the weeds are also killed. This leads in turn to sealing and crusting, and lower water infiltration rates, higher runoff and more erosion. This constitutes an important challenge, especially during the establishment of the plantations.

Farmers are often unaware of these negative impacts on soils. Interviews with farmers revealed that their understanding is that herbicides kills only the above-ground part of the plant – and leaves it as mulch which would be positive for infiltration, moisture conservation and soil fertility. Research results proved to be different. The practice of leaving naturally occurring undergrowth by less intense weeding, at least between the rubber rows, would help to solve one of the most serious problems in intense rubber cultivation: soil erosion by water (Figure 1.24). Improved management of undergrowth can range from changing chemical weeding, towards mechanical weeding, and on to maintaining undergrowth to cover the soil. The more diverse flora will offer habitat and niches for more diversified fauna. Furthermore, improved and adapted use and management of pesticides – or even better integrated pest management approach – will support diversification in fauna.

Without herbicide application the natural undergrowth thrives and contributes to high water infiltration rates and soil protection against erosion. Nevertheless, on the terraces, weeding is necessary to enable rubber tapping – which is carried out after nightfall because of the higher flow of latex in the trees. Natural undergrowth would hinder the working process (while concealing fauna (e.g. snakes)) in the lower visibility at night. A viable compromise is for the small terraces on which rubber trees are planted to be kept weed-free, but the slopes in-between left for natural vegetation to recover. This

Figure 1.23: Clean-weeded rubber plantation during the dry season (January) with tree rows on small terraces, Yunnan province, China. (Gerhard Langenberger)

Figure 1.24: Old abandoned rubber plantation: the natural undergrowth re-establishes, Yunnan province, China. (Gerhard Langenberger)

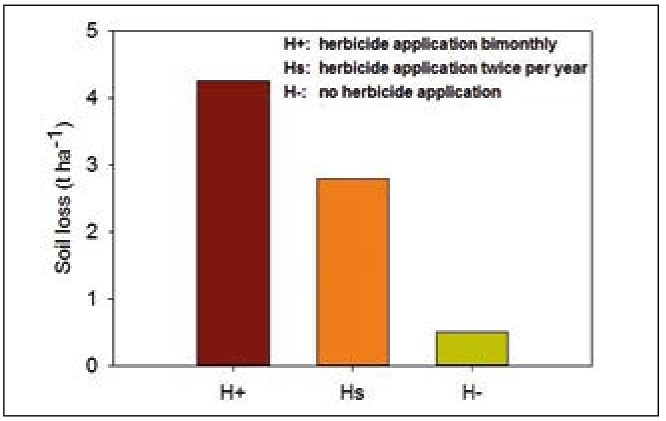


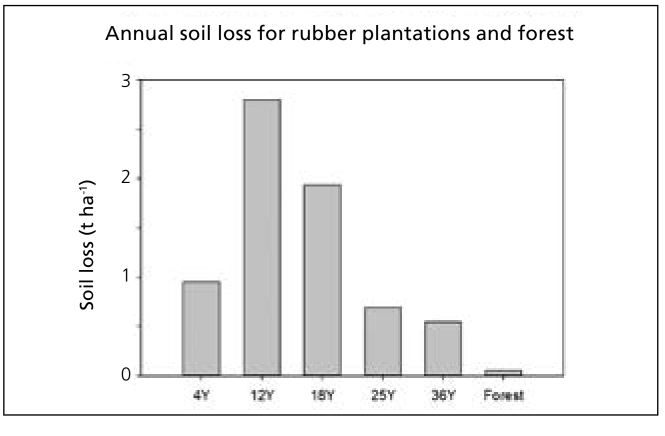
Figure 1.25: Annual soil loss in a middle-aged (12 years) rubber plantation Xishuangbanna, Yunnan, SW China, under different herbicide treatments (elevation 764 m a.s.l.; slope 29 degree) (Liu et al. 2016).

practice would contribute considerably to reducing soil loss by erosion, as tests with different weeding practices have shown (Figure 1.25). A first step would be to reduce herbicide application from the common twice per year practice to a once per year routine.

Furthermore, the age of the plantation has a considerable effect on soil erosion as is shown in Figure 1.26. At the age of four years, the rubber trees are still growing and the canopy still lets through some light. So some weeds survive and cover the ground in spite of herbicide treatment. At the age of 12 years, the rubber trees are fully developed and the canopy blocks out all light. The combination of lack of light and herbicide treatment results in complete eradication of undergrowth, which in turn generates the highest erosion rates. In later years the tree canopy becomes less dense, more light gets through, and the undergrowth has a better chance of covering the ground.

To control soil erosion economically and environmentally, intercropping of valuable native (ideally endangered, protected or red listed) tree species into rubber monocultures and leaving/ management of undergrowth was tested in Yunnan province (see Technology 'Native trees in rubber monocultures' page 191). These tree species contribute to soil stabilization, and also provide alternative income options to farmers. Keeping the natural undergrowth between the rubber rows, by avoiding chemical weeding, would considerably reduce erosion and thus soil organic matter/ carbon loss. Additionally, this would support plant as well as animal biodiversity. In rubber plantations, further viable solutions to enhance biodiversity and to improve environmental friendliness at a landscape level, are protecting stream bank vegetation (riparian forests), buffer strips, restricting the maximum size of a single continuous plantation, and establishing environmental corridors.

Figure 1.26: Annual soil loss in rubber plantations of different ages with herbicide treatment twice per year (Liu et al. 2016) as compared to forest (Li 2001).



Irrigation and salinization in the Tarim River Basin of the Taklamakan Desert, Xinjiang Province, China

Reducing salinization in Tarim Basin China

context: poor land and water management in production systems for cotton and other crops lead to saline soils

problem: soil erosion by wind, due to land abandonment and winter fallows in cotton cultivation, leading to contamination of other areas

solution:
– crop rotation (winter wheat) soil cover instead of fallow
– intercropping/ agroforestry with fruit trees
– conservation of riparian forests -> wind breaks
– apocynum (salinity tolerant multipurpose herb) cultivation -> soil cover in saline areas preventing erosion and at the same time providing income

message: making an opportunity out of a problem by the use of an indigenous halophyte (salt-loving plant) to cover land, protecting it from erosion, and to provide income

Cotton in the Tarim Basin of the Taklamakan desert, China, is an irrigation-intensive crop and from the perspective of water use, poorly suited to deserts. From the view point of cotton quality however, it is good to grow cotton in arid areas as humid conditions can lead to mould in the bolls. In Xinjiang, 300 to 400 mm per year water is needed for irrigation. Improper land and water (irrigation) management in production systems for cotton and other crops leads to saline soil (due to high and rising groundwater tables and high evapotranspiration, see Chapter 2 page 66) and eventually to abandonment by the farmers.

'Natural' groundwater is found at 7 to 8 m depth. By irrigating the land for crops, the groundwater table rises up to 2 m below the soil surface. Due to the fine soil texture and the high evaporation – of about 2000 mm per year – the salt and chemicals (fertilizers and pesticides) rise to the soil surface. The high sodium content leads to a disaggregation and dispersion of soil aggregates – creating a soil structure which engenders sealing and crusting of the surface. Furthermore, the salt on the surface is blown away and causes salinization in other areas.

After the harvest of cotton in the Tarim Basin, the surface is bare from October until the end of April (winter fallow) and susceptible to soil loss due to wind erosion. In addition, the saline, abandoned cotton fields are highly susceptible to wind erosion, and transport of saline soil particles leads to off-site salinization problems (Figure 1.27). Winds in the Taklamakan desert can become very strong and transport dust from the Tarim Basin to eastern China or further afield – as far as South Korea or the USA (Wang et al. 2008).

Figure 1.27: Salt crust formed on the soil surface, China. (Patrick Keilholz)

Figure 1.28: Intercropping: Fruit trees, for example apricot trees with winter wheat in Xinjiang province. (Christian Rumbaur)

Figure 1.29: Apricot trees planted in Xinjiang province. By selling the fruits farmers can earn more money than by planting cotton. Lower right corner: Drying apricots for the market. (Christian Rumbaur)

The combination of fruit trees such as apricots or Chinese dates, with annual crops such as wheat or cotton, would be an option to ensure at least partial soil cover after harvest of the annual crop (intercropping/ agroforestry) (Figures 1.28 and 1.29). An additional advantage is that these trees lower the groundwater level below the fields (a source of salinization) and give shade to the crops. These trees, as well as nearby riparian native vegetation, also act as wind breaks, slowing down the speed of the erosive winds.

To tackle the problem of salinized wasteland, salt tolerant Chinese and European dogbane species (*Apocynum pictum* and *Apocynum venetum*) were planted to provide permanent vegetative cover to the previously bare soil, and simultaneously ensure a source of income for land users (Figures 1.30 and 1.31).

Planting the salt tolerant species, *Apocynum pictum* and *Apocynum venetum*, can rehabilitate the saline wastelands that abandoned cotton fields have become. Rehabilitation is applied here in the sense that saline soils can be brought back into production again – but not implying that the soil is freed from the salts that had accumulated in it. The topsoil of apocynum plantations is often very saline, reaching salt contents up to 20%, but the lower soil layers have a salt content of only 1%. This shows that apocynum can grow on sites with pronounced surface salinization, as long as the subsoil and the groundwater are not strongly salinized. *Apocynum pictum* is a multipurpose perennial herb, and part of the natural riparian vegetation along the rivers of the Tarim Basin, that can withstand high soil salinity (see Technology 'Rehabilitation of saline soils' page 187). It is used as a medicinal plant (such as tea in traditional Chinese medicine) and as fibre crop. Thus farmers can earn money by planting apocynum – while protecting the soil at the same time.

1.1.2 Managing small-/ medium-scale agricultural systems

Eighty percent of the farmland in sub-Saharan Africa and Asia is managed by smallholders (working on up to 10 hectares) and they produce 80% of the food supply in Asian and sub-Saharan Africa (FAO 2012b). They are extremely important for food security, and provide livelihoods in the developing world. However, they also have a growing role in the developed world with regard to filling new production niches as demands increase for organic products, and natural forms of pest and disease management. Small-scale farming also has a role in mountainous areas or under difficult environmental conditions needing special attention, with their diverse and integrated land management practices.

Figure 1.30: Apocynum field in Xinjiang province. (Christian Rumbaur)

Figure 1.31: Apocynum pictum. a) plant with flowers, b) flowers, c) leaves, d) seeds. (Niels Thevs).

Investigations and results about improving small-scale agricultural production systems are presented from:

- Okavango Basin: improving small-scale agricultural yields with a mix of conservation agriculture (CA) practices on existing fields instead of shifting cultivation
- Madagascar: improving small-scale subsistence agriculture through integrated livestock management and agroforestry/ intercropping

Small- and medium- scale farming in the Okavango Basin

Stabilising crop production in the Okavango Basin

context: shifting cultivation and low-input agricultural practice is reaching its limits because of increase in the population and demand for production

problem: low yields for smallholders, lack of fertilizers, nitrogen limitation; low water and SOC, typical of semi-arid environments, but further depleted

solution: dryland conservation agriculture (combination of rip-lines or planting basins, crop rotation with nitrogen fixing plants and root inoculation, residue and soil cover management) to increase productivity of existing fields and prevent further expansion into woodland

message: sustainable intensification needs to be the goal wherever agriculture is practised – and conservation agriculture offers possibilities for a broad range of farmers: but it needs special adaptation for smallholders in Africa

The Okavango Basin stretches from the Angolan highlands through the northern parts of Namibia to its inland delta in Botswana. In its middle section, it is characterized by extended areas of sandy soils which are low in nutrient content; made worse by 'nitrogen-mining' through cropping, and depletion of their inherently low phosphorous and magnesium levels (Box 1.1). However, in some localised areas more nutrient-rich soils occur: in the Angolan highlands as well as on recent and former floodplains along rivers.

In the still-practiced shifting cultivation system, fertility of soils depends on the availability of land. However, several factors limit this: (i) rising rural population density, (ii) limited availability of fertile soils, and (iii) spatial expansion of cash cropping (monopolization of rural land via a few entrepreneurs). The effect of the land use practices become clear by looking at the decline of soil organic carbon in fields of the Kavango of northern Namibia: fields that have been used for decades (Figure 1.32). The overall organic carbon content is low, which is characteristic of semi-arid environments.

Box 1.1: The Okavango Basin: the nutrient problem

In the mid-river areas of the basin, a comparison between woodlands, fallows and cropped fields revealed that about 50 to 75% of total nitrogen, bound in organic substances, is lost due to crop production without fertilizer application. Within fallows, only a very slow increase in nitrogen content occurs, and phosphorous and exchangeable magnesium concentrations are not restored. The current, relatively young, traditional systems of the mid- and lower basin continue to depend on fallow as their prime fertility management measure (Jona Luther-Mosebach unpublished data).

A comparison of agricultural and woodland sites in Mashare showed that the current agricultural practice depletes the soil organic carbon stocks irrespective of the soil type (Figure 1.33). The mean loss of organic carbon is about 21 t ha^{-1} or -39 % of the initial amount in the natural forests/ woodlands since the conversion to agricultural fields some decades ago. As cultivation happened for a long period of time, it can be assumed that the amount of carbon on the fields today is relatively stable.

The official vision for agriculture in this region is often to increase yields by adopting industrial, large-scale agricultural production methods. But under the given soil and climate conditions, the transferability of those methods is very limited. Researchers have recommended a 'middle path' between small-scale subsistence and industrialised agriculture: sustainable intensification using a mix of conservation agriculture measures adapted to the local conditions. This strategy also benefits the local communities: farming their own land and creating income from it instead of losing land rights to large-scale farming companies.

In northern Namibia, dryland conservation agriculture (CA) has been promoted to improve crop production and, by raising yields, to reduce woodland conversion to cropland. Leaving plant residues in the field after harvest, applying manure in planting pits (or minimal soil-disturbing rip lines) were found to increase soil organic matter, improve soil fertility and nutrient availability. CA was tested on small plots of volunteer farmers (see Technology 'Conservation agriculture' page 247).

Figure 1.32: Typical field with low yield at the test site in Mashare. The Okavango River is in the background. (Alexander Gröngröft)

Figure 1.33: Soil carbon stocks (SCS) to 1 m soil depth within the experimental site at Mashare. Compared are woodlands and crop fields managed since decades for dryland agriculture on loamy and sandy soils. (Jona Luther-Mosebach)

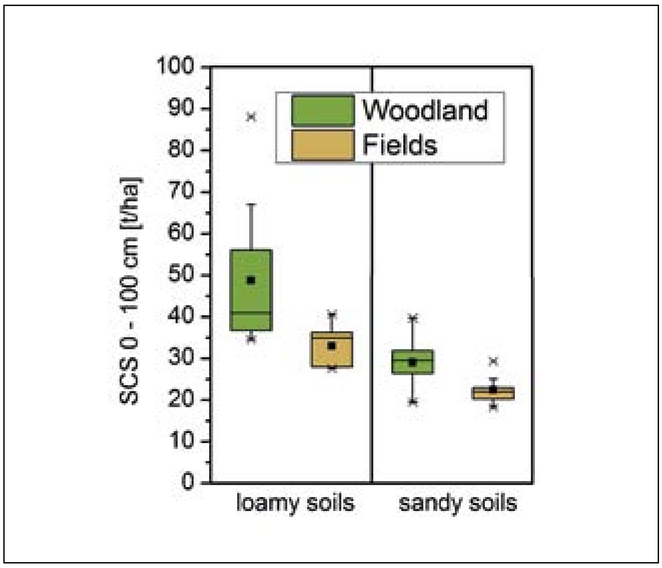


Figure 1.34: Planting pits in conservation agriculture are labour intensive but increase yields significantly, Namibia. (Alexander Gröngröft)

Figure 1.35: Poor nodulation of roots of cowpea in Kavango soils (left). Eefficient nitrogen supply from groundnut inoculated with a *Bradyrhizobium* sp. strain (bottom right) in comparison to non-inoculated control (top right) in vermiculite culture in the laboratory. (Barbara Reinhold-Hurek)

Mean yields of traditional farming system in Namibia were compared with the yields of experimental conservation agriculture plots. In these experiments, combined field inputs such as biochar, inorganic fertilizer and cattle manure with the water harvesting technique of planting basins/ rip lines (Figure 1.34) resulted in increased yields when the production of the different crops in the rotational and intercropping systems were combined. However, results only show the initial improvement of yields after two seasons of cultivation. Sustainable improvement of the soil is expected to lead to even higher yields – but this could not be evaluated within the short duration of the project (Table 1.2).

Table 1.2: Mean yields of the dominant smallholder farming system and the experimental conservation agriculture test site in Mashare, Namibia. (TFO)

Farming System	Type of crop	Yield (kg ha^{-1})
Traditional farming system (= rainfed permanent cultivation) planting pearl millet alone	pearl millet	221
Conservation Agriculture (= sustainable intensified cultivation) after 2 years, interplanting pearl millet, maize and cowpeas	pearl millet	243
	+ maize	227
	+ cowpea	180

The use of improved, more drought-resistant, crop varieties is relatively widespread in the Okavango Basin: 75% and 37% of farm households in the Botswanan and Namibian study site, respectively, do at least sometimes use improved seed varieties. However, inadequate soil fertility management, and lack of water harvesting practices, appear to be more critical bottlenecks to agricultural production than the genetic material itself.

Under dryland agricultural conditions in Mashare, Namibia, yields of the smallholders farmers are commonly low and mostly nitrogen-limited. As fertilizers are not applied in traditional cropping systems, soil fertility declines with the duration of cropping. Nitrogen supply may be enhanced by using nitrogen-fixing plants (legumes) in crop rotations or intercropping with the main crops. Nitrogen increment relies on bacteria capable of biological nitrogen fixation within root nodules (Figure 1.35). However, many of the bacteria are not adapted to the heat and climatic conditions. Field experiments in Namibia using selected *Bradyrhizobium* sp. strains as inoculants showed promising soil fertility improvements.

Fertility improvement through tree-crop-livestock integration in small-scale farming on the Mahafaly Plateau, south-western Madagascar

Small-scale farming system in drylands of Madagascar

context: dwindling land resources and soil fertility on the Mahafaly Plateau in Madagascar, population pressure: increasing need for food production, high malnutrition rates

problem: low soil organic matter content, low fertility and erratic climate conditions (low water availability and droughts) leading to recurrent crop failures

solution:
– integrated crop livestock management tested: corral shifting and measures to increase manure quality (by composting – including household wastes and crop residues and/or better storage)
– home gardens: intercropping/ agroforestry with adapted and desired species

message: an important element of sustainable intensification in small-scale farming is fertility management: manure and compost are vital additions to the soil and both agroforestry and intercropping with legumes have an important role to play

Due to unpredictable climatic conditions with a high risk of yield loss (depending on the crop), farmers on the Mahafaly Plateau in Madagascar do not invest much capital in agricultural intensification (e.g. fertilizer) or for the plant material (seeds, cuttings) used in crop production. Crop yields are below the national average – and far below international averages (Hanisch 2015), reflecting water and soil nutrient deficiencies. The lack of organic fertilization and amendments leads to a significant loss of organic matter (carbon and nitrogen) in the soil (Box 1.2).

Box 1.2: Organic material in fields compared to forests on the Mahafaly Plateau, south-west Madagascar
On average, in comparison to forests, crop fields have only 19% of the organic material, and after a one-year fallow only 25%. These results indicate that fallow fields recover slightly, but measurably, in the first year of the fallow period (Hanisch 2015).

Due to dwindling land resources and soil fertility, intensification of cropping systems it is necessary to increase the agricultural productivity and food self-sufficiency of smallholder farmers (Figure 1.36).

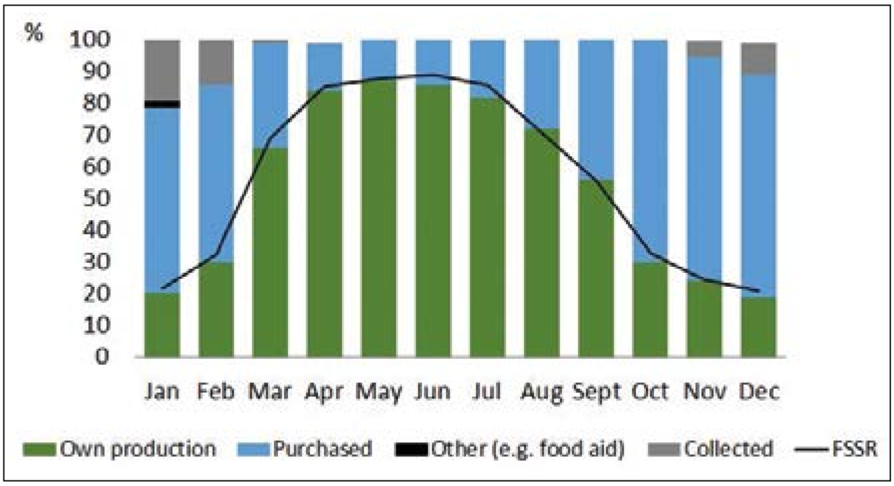


Figure 1.36: Sources of household food consumption (%) and food self-sufficiency ratio (FSSR) (%) per month on the Mahafaly Plateau, SW Madagascar for 2013. There is a high rate of chronic malnutrition in this area. Up to 20% of food consumption was gathered from forest resources using edible forest food (collected). Only 25% of the households are food secure. (Noromiarilanto Fananbinantsoa)

The potential of integrated crop/ livestock management was tested. Traditionally, no chemical or even natural soil amendments, such as cattle manure, are applied in the field and livestock dung accumulates unused in the corrals (Figure 1.37). However, results of fertilization trials with local manure showed no clear improvements on crop yields. Livestock manure currently available in village livestock corrals was demonstrated to be of low quality due to the long storage period and poor storage conditions. The cattle manure in particular that was used in the experiment had a carbon/nitrogen (C/N)-ratio of 15.3 to 25.8, which was much poorer than the C/N-ratio of the untreated soils in the field plots with a mean ratio of 11.9 (Hanisch 2015). This was a typical situation for the whole study area where the C/N-ratios on crop fields had an average C/N-ratio of 10.9 (n = 22, range from 6.4 to 15.4). Goat manure was of higher quality than the cattle manure with a C/N-ratio of 8.4 (Hanisch 2015). Furthermore, the very dry consistency of the manure collected from corrals displayed hydrophobic properties – thus repelling water, and this might have contributed to the absence of a positive effect under the local circumstances where there was a very limited availability of water. It was concluded that freshly produced and appropriately stored or composted manure should be used.

To improve manure quality, composting of household wastes and crop residues are currently being promoted in the area. Important improvements in manure storage may be achieved through flooring and roofing of the manure collection sites. Even if manure is currently not available in sufficient amounts in the study area (due to relatively low livestock densities), small-scale manure application in homegardens should, in theory, be easily adoptable and would increase soil fertility. The practice of shifting corrals after several years, to use the fertile site of the former corral for crop cultivation, may be the most easily adopted strategy – and could be promoted further to create patches of fertile soil and reduce labour costs that are often considered as a crucial factor inhibiting adoption of manure use.

Vegetable production in homegardens can be a feasible diversification strategy for food security and possibly for income too. This can be improved by the deliberate inclusion of trees and shrubs, alley cropping and agroforestry systems with drought tolerant crops – millet and sorghum instead of maize. Homegardens with agroforestry components are still very scarce, but increasingly promoted in the Mahafaly region through the distribution of fruit trees such as mango (*Mangifera indica*), papaya (*Carica papaya*), citrus spp., drumstick tree (*Moringa oleifera*), and several leguminous tree species (*Sesbania sesban*, *Leucaena leucocephala*, and *Acacia auriculiformis*) (Hanisch, 2015). Additional vegetables such as onions or carrots can be planted between the papaya trees if regular irrigation is possible (eg with household wastewater), and homegardens should be fenced-off to protect them from grazing animals.

1.2 Managing irrigation and fertilization

Highly productive systems – besides needing appropriate plant genetic material – rely on sufficient and continuous water and nutrient supply. Most agricultural land, globally, is rainfed, implying that it relies entirely on precipitation and the water storage in the soil. Similarly, the nutrient supply from the soil also needs to be guaranteed. However, shortages of water and nutrients during the growing period lead to serious reduction in crop yields – or even crop failures. Furthermore, inputs of water and nutrients need good land management, otherwise this can lead to serious land degradation – or water conflicts.

Figure 1.37: A typical corral in the littoral area of the Mahafaly region, Madagascar (left); the accumulated manure is very dry with hydrophobic properties (right). (Tobias Feldt)

1.2.1 Managing irrigation

A major concern for intensified agricultural production is the supply of irrigation water in areas where rains are not sufficient. This may be either in total (in semi-arid or arid environments) or during critical times of the crop production cycle (in all climates). Climate change and climate extremes will increase water stress. Irrigation is costly, and has inherent dangers related to water conflicts and salinization. Irrigation usually implies heavy investment and a different, mostly intensive and production-oriented, system in order to pay for the high costs incurred. Apart from the high costs, irrigation systems have to assure reliable water supply and acquisition of non-conflicting water rights. Salinization is a common threat to irrigation systems especially in the drylands, thus needing special attention and 'smart' water management practices. Poorly maintained irrigation systems can lead to inefficient, ineffective and costly water use.

The three examples that follow show that water use efficiency is usually not achieved through a stand-alone technology, but a mix of practices treating more than one problem, and by combining technologies with governance measures. The examples are:

- Improved drip irrigation and flooding, and reduction of salinization from northern China
- Improving water use efficiency, re-use of irrigation return water, and mitigating salt water intrusions from the river delta in Vietnam
- Improving incentives to increase water use efficiency and updating technologies for reservoir water use in Brazil

Irrigation management against water scarcity and salinization in the Tarim River Basin in the Talamakan Desert, Xinjiang Province, China

Large-scale irrigation of cotton in the arid lower Tarim Basin
context: cotton, a water-demanding crop in the arid lowlands of the Tarim river, is the main source of income. Large irrigation schemes secure yields in the cotton cultivation areas along the Tarim river
problem: high evaporation and salinization through irrigation, and pollution by agro-chemicals
solution: mix of measures: drip irrigation, drainage system and water treatment/ adapted irrigation practices (winter flooding)
message: commonly, salinity affects efforts to achieve high yields through irrigation, and over-use of agro-chemicals also threatens sustainability. A mixture of measures needs to be considered – often specific to the area – in order to remedy the situation

The Chinese government began to promote cotton production in Xinjiang in the 1980s. The dry climate and the long duration of sunshine hours make the region potentially suitable to produce cotton of high quality – although in Xinjiang it requires an average of 400 mm of water per hectare. Nevertheless, cotton has become the major crop and source of income in Xinjiang: here 40% of the total Chinese cotton is produced, representing about 12% of the produced cotton worldwide.

However, as noted, cotton is a water-demanding crop and large irrigation schemes have been required to secure yields in the cotton cultivation areas along the Tarim River. In fact, due to the low precipitation and the high evaporation rates, the region's water supply depends solely on the Tarim River water. During the summer, the river is fed mainly by glacier and snow melt, which causes floods but also fills the irrigation reservoirs and channels. Irrigation indeed is the biggest water user in the area.

Figure 1.38: Drip irrigation under plastic mulch,China. (Christian Rumbaur)

The current irrigation practices however are also the main cause of the soil salinization that has affected the area. Furrow irrigation and repeated flooding without drainage lead to high groundwater tables. In soils with high capillary rise potential (i.e. soils with a high proportion of fine sediments such as silt), the resulting high evapotranspiration increases the rate of salinization. A very effective technical measure to lower the groundwater table in cotton fields comprises drainage channels that return surplus irrigation water back into the river – though a major disadvantage is the high implementation cost. Drainage pipes have to be buried below the root zone of the crops. Consequently, these measures are not implemented, as long as there is enough accessible arable land in the region. Hence, the common practice is to cultivate a field and allow deterioration of the soil for as long as possible. If salinization impacts then render the fields unproductive, they are abandoned and new fields are cultivated.

One alternative to the costly underground drainage is to build simple side drainage channels along the field borders. But such drainage practices have trade-offs with water quality in the lower reaches of the basin through the accumulation of salts, nutrients and pollutants in the return water. Drained irrigation water containing salts and agro-chemicals is channelled back into the river and pollutes it. The end users not only have less reliable water flow, but also lower quality. Drainage water should not be directly led back to the Tarim River, it ought to be captured and treated in wastewater treatment plants to reduce the salt content. This treated water can then be discharged back in the Tarim River. However, such water treatment is very expensive and therefore not up for discussion currently.

To improve the water quality and quantity in the Tarim River, drip irrigation under plastic mulch was tested – and recommended to be introduced over the whole region (see Technology 'Drip irrigation in cotton' page 183). Drip irrigation helps to save water during the growing period because of its inherent water use efficiency. Hence, more water becomes available for other purposes, for example ecologically beneficial flooding of the riparian forests. Also, with drip irrigation, the groundwater does not rise during the growing season. However, a saline soil layer below the roots of the cotton plants will develop. Therefore, after harvesting and before seeding, the fields are flooded to leach the salts to deeper soil layers where it does not affect the roots of the plants. The combination of drip irrigation and seasonal flooding thus prevents salinization of productive soil. But this combination of practices leads to almost no overall water saving compared to furrow irrigation.

However, if flooding is carried out before the winter (after harvesting), the water and soil freezes, and the water is thus stored in the soil until spring and is available for germination and the initial growth of crops – meaning that additional irrigation is only needed in late spring and summer. Additionally, in late autumn, there is more rain and river flow from the mountains that can be used for the flooding of the fields. The water saving from drip irrigation during the growing period reduces water demand during the dry summer period, and thus increases availability of irrigation water. It also improves the water supply to natural vegetation (especially riparian forests) in the critical summer period.

To render drip irrigation more efficient and decrease evaporation in this hyper-arid region inter-row spaces in cotton fields are covered with plastic mulch (Figure 1.38). In 2014, 185,000 metric tons of sheeting were used in Xinjiang, but the recycling rate only averaged 40 to 50 percent, which caused a waste problem. During recent years, machines have been developed to collect the plastic film discarded in cotton fields. If the plastic film meets the new standards (0.01 mm of thickness instead of 0.008 mm) up to 90% can be collected. The thicker plastic increases the success of recycling efforts, because it does not tear so easily.

Figure 1.39: Paddy fields in Vietnam. (Dominic Meinardi)

Improving water use efficiency and reducing salinization in Vietnam

Irrigation efficiency in paddy rice production
context: water availability for paddy field irrigation especially towards the end of the dry season
problem: multiple claims such as abstractions of river water for irrigation and diversion and storage of water for hydropower generation as well as salt water intrusion lead to a decrease in water quantity and quality
solution: reusing return flow
message: reusing return flow is a good example of where innovative thinking combined with research support can help answer serious challenges in agriculture

Due to abstraction of river water for irrigation, diversion and storage of water for hydropower generation – and salt water intrusion - less water is available for paddy field irrigation especially towards the end of the dry season (Figures 1.39 – 1.41 and see Chapter 2 page 50).

Reusing return flow is regarded as a potential measure to reduce the severity of irrigation deficits in dry periods (see Technology 'Reuse of return flow in rice' page 271). If the surface return flow is carefully collected before entering natural rivers, it can be used as a supplementary source of agricultural water supply. Return flow can be collected by drainage canals and stored in tanks such as ponds, reservoirs or depressions. When the salinity of river water exceeds the threshold (1%), return water is pumped back into irrigation canals to dilute the river water.

Furthermore, through the purification function of paddies, which has been documented by previous research, return flow is of acceptable quality for irrigation. Paddy fields have the capacity to absorb nitrogen and phosphorus (Kunimatsu 1983; Feng et al. 2003; Hitomi et al. 2006). Because of the sandy soils of the rice fields in Vietnam, the fertilizers and pesticides are filtered out of the water. The water quality testing results also indicate that return flow from paddy fields is suitable for irrigation: they meet the irrigation water quality standards of Vietnam (QCVN: National Technical Regulation on Industrial Wastewater, Ministry of Natural Resources and Environment). For instance, low total dissolved solids in water, all below 400 mg/L, showed the purity of the return flow. The threshold of the irrigation water quality standards of Vietnam (QCVN) is 2000 mg/L. The return flow helps to extend the irrigation sequence and increase irrigation efficiency.

Increase water use efficiency and updating technologies for reservoir water use in Brazil

Improving incentives for increasing water use
context: periods of prolonged drought will increase and exacerbate water scarcity already common in the region
problem: inefficient water use (e.g. outdated irrigation technology and practices) and large water losses due to indiscriminate and uncontrolled water use, improper irrigation management leading eventually to soil salinization
solution: water pricing as an incentive for more efficient use improve irrigation infrastructure or irrigation timing (at night/ in the evening) to reduce evaporation
message: economics can be used as a tool to make irrigation more effective: thus raising water costs to users can be considered alongside technical measures to improve efficiency

Even though climate models are contradictory regarding projections of future rainfall, in the São Francisco River Basin, Brazil a general finding is that weather extremes will increase, and that even in a wetter scenario the periods of prolonged drought will be more common. This region has water scarcity problems already – under current climate conditions. They are caused by inefficient water use (e.g. outdated irrigation technology and practices), huge water losses from reservoirs (e.g. due to evaporation) and indiscriminate and uncontrolled water use (illegal over-abstraction) leading eventually to soil salinization as well.

In general, users have to pay for water abstraction above a defined threshold (currently 4l/sec from the São Francisco River). In irrigation schemes, which originate from 'compensation' for damming to create the Itaparica reservoir, the hydropower company pays for water consumption but does not pass on these costs to the farmers who use the water. The reasons for bearing the costs instead of passing bills to farmers are probably due to:
1. unclear land tenure and land water use rights, and pending compensation payments of the hydroelectric company expected by the displaced people after flooding their former land;
2. unclear organizational issues and responsibilities, such as maintenance of the facilities, equipment and infrastructure; and
3. inappropriate irrigation design and infrastructure, such as too-wide spacing of sprinklers, with over-irrigation in some places and under-irrigation in others.

Land tenure, and land and water use rights are a key issue behind improved soil, water and biodiversity management, and assigning an appropriate price for water (including irrigation and electricity needed for pumping water) is a necessary incentive for more

Figure 1.40: Tu Cau irrigation canal stops working due to salt intrusion impacts in Vietnam (March 2013). (Tran Thi Ha Van)

Figure 1.41: Tu Cau pumping station, Vietnam. (Tran Thi Ha Van)

sustainable use of water resources. However, introducing a water and energy price needs to be done gradually to allow farmers to adapt to new production conditions. As a first step, and in order to increase the awareness about the value of water, simulated water bills were issued to the water users. These gave farmers an idea of the costs that are to be expected in the future. Some farmers reacted with ignorance or annoyance and went about their business as usual. Others took them seriously, and consequently pioneered the reduction of irrigation water use; for example replacing sprinklers with the more efficient system of micro-spray (best for coconut and banana plantations) or drip irrigation, depending on main crops to be grown. Moreover, it is important to install an adequate and functional drainage system, something not realized during the initial infrastructure installation.

Another measure to increase water use efficiency is changing the timing of irrigation - from day to night to reduce evapotranspiration losses. However, the drawbacks of such a change are that irrigation during day time is – obviously – more convenient for farmers, as some plots are distant from their homes and irrigation practices need considerable on-the-spot work. A more realistic option would be to irrigate very early in the morning (or late afternoon) when evaporation is less severe. However, given the antiquated, unreliable and work-intensive irrigation infrastructure, this would inevitably mean some irrigation during the night. The current irrigation systems are often very outdated, leaking and hard to repair causing further water losses. Investment in modern technology could be combined with the installation of water abstraction monitoring meters necessary for water bill implementation. This case demonstrates the importance of a coordinated, multifaceted approach to solve the water scarcity problem, requiring the cooperation of the different stakeholder groups involved.

1.2.2 Fertilization and soil enrichment

Just as water is crucial, availability of nutrients and their management is a central precondition for successful agricultural production. SLM strategies in agriculture are based on designing production systems that are best adapted to the local conditions in terms of crop choice and management practices (mixed farming systems; no-till, crop rotation, intercropping, agroforestry etc.) to secure soil fertility, and the ready availability of nutrients.

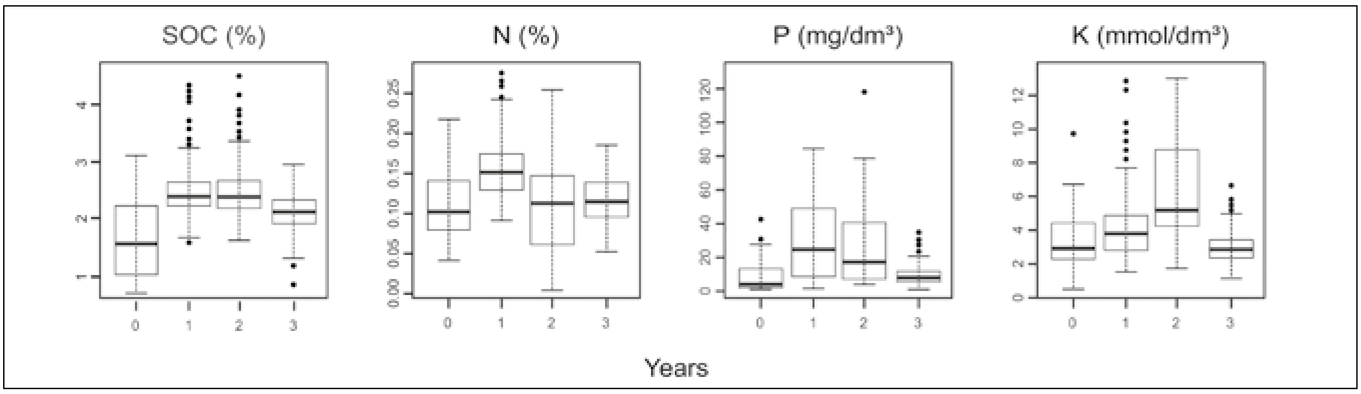
In some cases, additional inputs including fertilizers and soil additives are necessary in production systems with nutrient deficiencies due to natural conditions, due to production practices or both. Examples to illustrate this are related to:

- Soil enrichment (locally available amendments) in commercial crop production in Brazil's *Cerrado* rainforest
- Soil enrichment with biochar in the *Caatinga* biome, Brazil
- Silicon fertilization in intensified rice production, Vietnam

Soil enrichment in the Brazilian *Cerrado*

Methods of soil enrichment in the Brazilian *Cerrado*
context: decreased yields due to steadily decreasing soil fertility
problem: reduction of SOM under intensive use and ploughing; low SOM
solution: soil enrichment with low cost, locally available soil organic amendments, positive effects apart from fertility: waste recycling
message: impoverishment of soils is inevitable under crop production systems unless nutrients are returned to the system. Locally available materials should always be the first priority

Figure 1.42: Effects of soil enrichment on different nutrients and soil carbon in years after application, Brazil (Luisa Vega unpublished data).



Intensive cultivation of monocultures in the southern Amazon and the Brazilian *Cerrado* leads to a decrease in soil fertility, due to soil organic matter depletion, and hence a decrease in nutrient availability. In the southern Amazon and the Brazilian *Cerrado*, on-farm experiments were performed to enrich tropical agricultural soils with different types of organic matter (OM) in the medium term (see Technology 'Organic matter amendments' page 159). The effect of different types of OM amendments on soil organic carbon (SOC) and macro-nutrients (N, P, and K), soil physical properties (water holding capacity) and crop yield (soy and corn biomass and grain production) were assessed. The amendments included filter cake of sugar cane residues, sawdust from *peroba* and *cedrinho* (used in the timber industry), coarse chips of *Eucalyptus* sp. and biochar. The applied amendments are locally available and are considered either cost-efficient or waste materials. The addition of OM amendments is a win-win situation constituting both a solution for organic matter waste recycling, and improving soil quality. The amendments have to be repeated every two years because in the third year after application, effects decrease considerably (Figure 1.42).

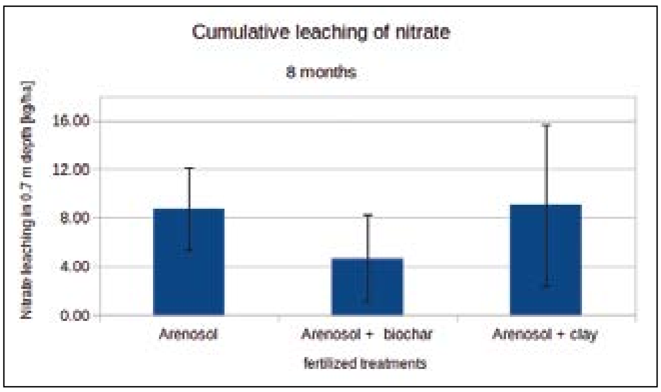
However, care should be taken not to use amendments that might, potentially, have a negative or toxic effect on plant growth such as coarse chips of *Eucalyptus* sp. – or consider pre- treatment before application to reduce or remove toxic effects.

Biochar enrichment in the *Caatinga* biome, Brazil

Biochar and clay as possible soil amendments
context: low productivity of sandy soils of the São Francisco Basin; resettlement of land users on less fertile land due to new reservoir
problem: low soil organic matter, low soil fertility
solution: soil organic amendments with biochar, clay and goat manure
message: biochar is an ancient method of improving soil fertility in the long term – one which has been recently re-discovered. Soil enrichment should look equally to both ancient and modern methods

To support agricultural production on the less fertile sandy soils of the São Francisco River Basin (Arenosols), the potential to ameliorate them through addition of soil amendments (biochar, clay, and goat manure) was tested. During the 23-months experiment no significant treatment effect on shoot growth and survival of *umbuzeiro* seedlings (*Spondias tuberosa*) were observed. However, the root system responded to the amelioration of the coarse-textured soil. Goat manure application led to the highest soil water content and reduced the soil bulk density, which had a significant positive effect on root tuber growth. Neither biochar nor clay amendments had a significant effect on seedling performance.

Figure 1.43: Comparison of cumulative leaching rates for nitrate, 8 months after fertilisation for an Arenosol soil without or with different soil enrichments measured at a depth of 0.7 m, Brazil. (Christine Beusch)



The effects of additions of biochar and clay sediments from temporarily dried up dams on the growth of the native tree *umbuzeiro* were compared, and the effects on nutrient retention for nitrate, ammonium, and potassium were analysed (Figures 1.43 – 1.45).

Adding biochar and clay to a sandy soil (Arenosol) showed effects of soil fertility enhancement through an increase in nutrient retention. The effects varied with different amendments and nutrients. Compared to the original soil, biochar amendment increased the nutrient retention during the first 8 months for nitrate (by 57%), ammonium (by 47%) and for potassium (by 18%). The addition of clay increased nutrient retention for ammonium (by 55%) and for potassium (by 41%) but showed no effect for nitrate.

Adding carbon to the soil in form of biochar increases the soil's storage capacity for most nutrients even in sandy soils, and simultaneously enhances carbon sequestration. Similarly, the addition of clay shows a trend towards increased retention of nutrients. Biochar and clay as single soil amendments do not add a noticeable quantity of nutrients, their impact is only seen in combination with organic or mineral fertilization. Biochar and clay are also used to ameliorate the soil structure. Overall, it appears that biochar and clay might be useful and their application can be feasible for annual crops on intensively used agricultural plots, more than for slow-growing perennials (e.g. fruit trees).

One of the locally available resources for the production of biochar comprises coconut husks, after coconut water is extracted in local factories. These husks are currently underutilized, just thrown away, forming garbage dumps nearby the factory (Figure 1.46). Laboratory test of biochar production from coconut shells showed promising potential for use as a soil enrichment and for long-term fertilisation.

Figure 1.44: Comparison of cumulative leaching rates for ammonium, 8 months after fertilisation for the soil type Arenosol without or with different soil enrichments measured at a depth of 0.7 m, Brazil. (Christine Beusch)

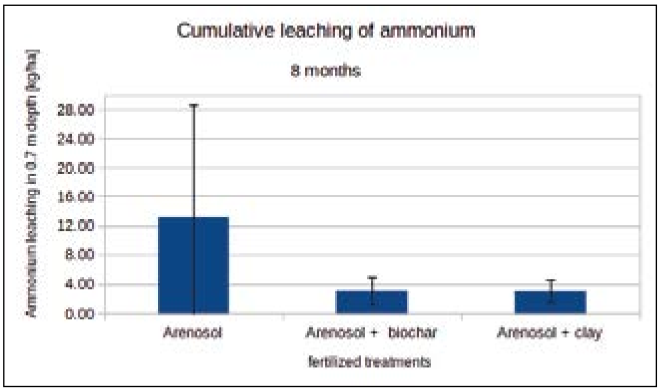
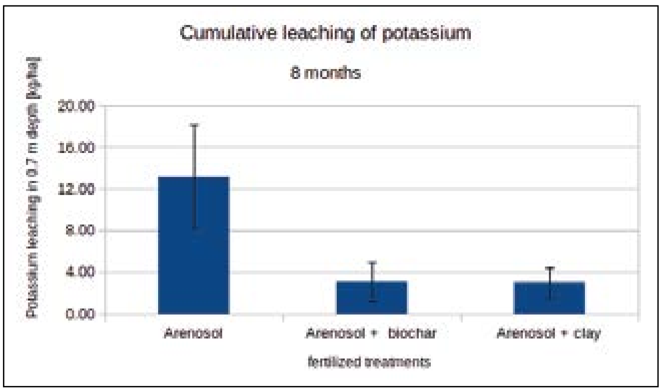


Figure 1.45: Comparison of cumulative leaching rates for potassium (K) 8 months after fertilisation for the soil type Arenosol without or with different soil enrichments measured in 0.7 m depth, Brazil. (Christine Beusch)



Silicon fertilization in silicon-poor areas with intensified rice production, Vietnam

Silicon deficiency in rice production in Vietnam

context: in Vietnam silicon availability is a key to sustainable rice production. Silicon deficiency is an inherent natural soil condition, and silicon is exported from the fields by removing straw residues with the harvest

problem: silicon deficiency in soil (when a limiting factor) impedes rice plant growth. Silicon is important for resistance against pathogens and against uptake of toxic metals

solution: testing silicon fertilization, and research to better understand the silicon cycle including causes of low concentrations in soil and impact on yields; not removing harvest residue from the fields (residue management)

message: it is easy to become too focussed on the common macronutrients (N, P, K) in soils and organic matter levels – but sometimes the primary limiting factor in crop production is a less obvious nutrient (or nutrients) and soil tests should always be carried out to establish such deficiencies

Although silicon (Si) is the second most abundant element of the earth's crust, in some soils silicon deficiency limits plant growth. In Vietnam, silicon availability is key to sustainable rice production (Box 1.3). Silicon can improve rice crop resistance against pathogens, pests and abiotic stresses such as salts, drought and storms, as well as preventing the uptake of toxic metals (Cooke and Leishman 2011; Guntzer et al. 2012). But in some of the Vietnamese paddies, plant-available silicon concentrations are below critical values.

To better understand the Si-cycle in irrigated paddy fields, researchers studied 4 Vietnamese and 3 Philippine regions (10 fields per region). The concentrations of readily available Si in the topsoil (estimated by extracting Si from soil with acetate solution) were found to be significantly higher for Philippine than for the Vietnamese regions (Klotzbücher et al. 2015). A larger pool of weatherable primary silicates in Philippine soil is the (possible) main reason for the finding.

Box 1.3: Silicon as a limiting factor
Silicon deficiency in irrigated rice paddies within some areas of Vietnam is a key limiting factor to rice yields: Plant-available Si concentrations in topsoils of paddies greatly differ between Philippine (141–322 mg Si kg–1) and Vietnamese (20–51 mg Si kg–1) regions. Higher Si concentrations in the Philippines are due to recent rock formation by active volcanism, and a large Si input due to mineral weathering in recent geologic history. Land use can also affect plant-available Si in topsoils (Klotzbücher et al. 2016).

Mean Si concentrations in rice straw ranged from 3.0 to 8.4% within the studied regions. For most of the Vietnamese fields they were lower than the critical value of 5.0%, suggesting a Si limitation to plant growth. In fields with low Si availability, both Si concentrations in the rice straw and acetate-extractable Si in topsoil (i.e. dissolved and adsorbed Si) were low. Such a relationship was not found for fields with high Si availability, presumably due to a maximum Si uptake capacity by rice plants. (Klotzbücher et al. 2016).

Silicon fertilization experiments in lowland rice in Vietnam (Marxen et al. 2016) prove the positive effect on rice yields (Figure 1.47). Increasing Si availability in a soil with originally low plant-available Si increases Si uptake by rice plants and plant productivity (total above ground biomass and grain yield) as well as the decomposability of the produced straw. Current results show that Si fertilization could increase yields in some regions in Vietnam, but no cost-benefit analysis has been carried out so far.

Figure 1.46: Dumped coconut husks near a local factory, Brazil. (Marianna Siegmund-Schultze)

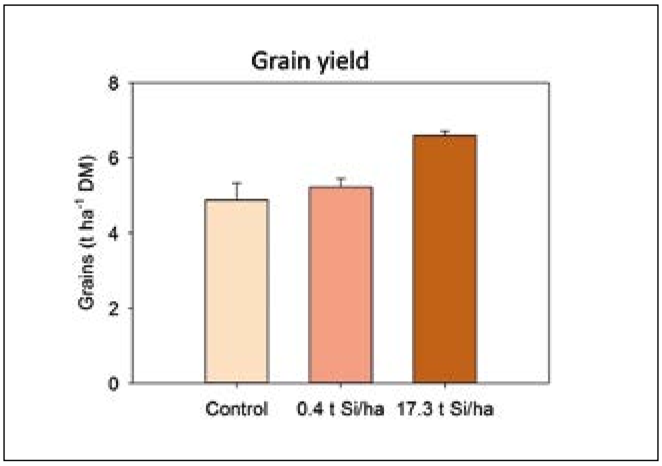
A common practice of many Vietnamese farmers is to 'export' Si from fields by removing straw residue with the harvest. On silicon-deficient soils a first step to improve the silicon supply to plants would be to change the current harvest residue management system and leave straw on the fields. Additional silicon fertilization could further increase yields, if Si deficiency indeed is the bottleneck to plant growth. To make effective decisions about suitable fertilization, soils need to be analysed, and farmers provided with relevant information about what kinds of nutrient are needed in each case.

1.3 Eco-engineering

An interesting strategy is the purposeful design of agricultural systems that integrate natural elements of ecosystems to improve production or remedy negative impacts of production. Using ecosystem services (ESS) in this quasi-technical way is termed 'eco-engineering'.

Examples are presented from:
- The Philippines: transferring the concept of flower strips along production fields into lowland rice production systems
- Brazil: using a composition of plants and bacteria as a natural purification plant for fish ponds

Figure 1.47: Grain yield of test fields with different amounts of Si fertilization (Vietnam): Control - no fertilization; 0.4 t Si/ha testing an application rate that would be feasible for farmers to apply in economic terms; 17.3 t Si/ha testing a high application rate to produce silicon-rich straw for laboratory experiments; DM: Dry Matter (Marxen et al. 2016).



Ecologically engineered rice production in the Philippines

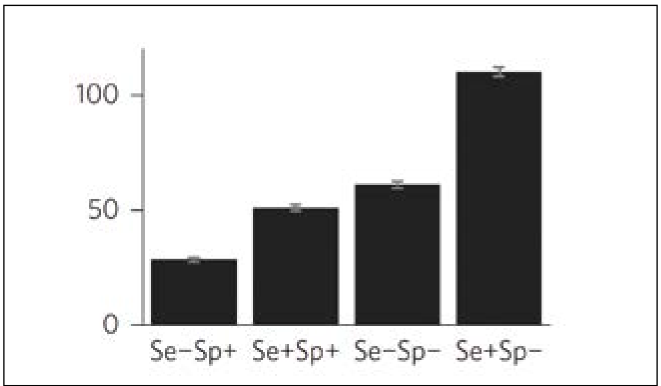
Biodiversity for rice production
context: high input of agro-chemicals in lowland paddy rice production systems
problem: biodiversity degradation/ decline in intensely used monocultures; increasing use of pesticides; cause of secondary pest outbreaks, etc.
solution: informed and lower use of pesticides/ agro-chemicals, integrated/ biological pest management/ ecological engineering
message: harnessing the natural processes of nature can bring surprisingly large benefits to help solve agricultural problems in a creative way

In rice production systems, mainly lowland paddy rice, one creative measure to improve biodiversity is to decrease or even stop using pesticides and to turn towards integrated biological pest management or 'ecological engineering'. The newly introduced concept of 'ecological engineering' aims primarily at the regulation of pest species through the management of natural enemies' habitats (diverse, flower-rich and complex in structure). Other ecosystem services, such as pollination, cultural services, aesthetics and the recreational value of agricultural environments may be simultaneously enhanced with the same measures. Biological pest control, pollination services and landscape aesthetics can benefit from the establishment of flower strips around rice paddies at the local level, and in the rice production landscape of Munoz, Nueva Ecija, region of Central Luzon, Philippines (see Technology 'Ecological engineering in rice' page 263).

Abundance and species richness of functionally different taxa (e.g. bees, hoverflies, beetles, spiders, parasites, and birds) can be increased by sown flower strips in agricultural landscapes. Many studies have evaluated the beneficial effects of flower strips in industrialised countries. This is a test of how best to transfer this concept of biodiversity-friendly management options for intensive crop production systems in the tropics, and especially in rice (Westphal et al. 2015).

First research results show that biological pest control, pollination services and aesthetics can benefit from the establishment of flower strips in rice production landscapes (Figure 1.48). The nectar-producing plants led to a measurable effect on primary productivity in the form of enhanced grain yield that in turn led to changed farm practice in the form of reduced spraying intensity, while providing increased economic benefit. However, more experimental studies are needed to test the benefits of different plant species. Rice farmers can better appreciate the benefits from regulating ecosystem services and should be involved in the development and implementation of ecological engineering. Combining participatory approaches and mass media campaigns with the establishment of flower strips and other beneficial habitats has the potential to increase sustainability of rice production in Asia.

Figure 1.48: Numbers of predators on pests in rice fields without, and with, the presence of nectar-producing plants (sesame) on bunds around the fields, Philippines. The treatment are Se–Sp+: no sesame border, crop sprayed; Se+Sp+: sesame border, crop sprayed; Se–Sp–: no sesame border, crop unsprayed; Se+Sp–: sesame border, crop unsprayed. (Gurr et al. 2016)



Eco-friendly water purification in the Itaparica reservoir of the São Francisco River in Brazil

Clearing polluted water from fish ponds
context: The recent development of commercial aquaculture (mainly in net-cages within the Itaparica reservoir, but also nearby in land-based tanks using water from the reservoir) is threatening water quality in the reservoir, which is used for irrigation water, drinking water and leisure activities
problem: Pollution of water going into the reservoir through surplus fish feed, droppings, and fish drugs
solution: land-based aquaculture and eco-friendly water purification ('green liver') instead of nets in the lake
message: it is important to recognise when pollution from productive activities begins to have negative impacts: and then to strive to control this by biological means wherever possible, without compromising production

The recent development of commercial aquaculture (mainly in water net-cages within the reservoir, but also nearby in land-based tanks using water from the reservoir) is threatening the water quality of the reservoir, which is used for irrigation, drinking water and leisure activities. Surplus feed from net-cages, along with droppings of fish, increase the nutrient content of the reservoir water, in particular P, but also residues from fish drugs.

Land-based aquaculture (excavated fish ponds next to the reservoir, but using its water) has the potential to reduce harming the reservoir's water body (less eutrophication, less veterinary medicine etc.). However, when the pond water is replaced with fresh water, the effluent from the ponds needs to be treated before releasing it into the reservoir/ river. With growing water scarcity, water quality can once again become an issue. The 'Green Liver' system has been tested as a prototype in one location of the reservoir. Installed between the fish ponds and the reservoir, it is able to purify aquaculture effluent from land-based water tanks, complying with official regulations for water quality. First runs have been optimized to purify water from fish drug (oxytetracycline) residues (see Technology 'Green Liver' page 167).

Table 1.3: SWOT analysis of the 'Green Liver' technology (Erika Marques)

Strenghts	Weaknesses
• Clean technology • Sustainable use of natural resources • Compliance with legislation • Reduction of harmful environmental impacts of fish farming • Cheaper implementation costs compared to other purification technologies	• Requires periodic maintenance • The efficiency of the system varies depending on season • Water quality degradation due to plant senescence • It can be invaded by fish (and fish feed on the macrophytes) • It can form a deadly trap for unherded small ruminants
Opportunities	**Threats**
• Favourable climate • Hundreds of dams, where it can be applied • Income and work opportunity for local population	• Seasonality • The common water hyacinth (*Eichhornia crassipes*) can invade the reservoir and become a plague if not well maintained

Figure 1.49: Herds of zebu cattle in the coastal plain area, Madagascar. (Johanna Goetter)

Experiences showed that maintenance of the 'Green Liver' system needs close monitoring and management. Young fish enjoy feeding on the macrophytes responsible for water purification in the 'Green Liver'. Thus fish spawn or fingerlings (small fish) need to be filtered out of the effluent before it reaches the 'Green Liver' ponds. The filtering of water flowing into the 'Green Liver' needs close observation, avoiding any by-passing or overflow. The whole system requires a goat-proof fence – because goats often jump into the ponds. Before upscaling the technology, further long-term monitoring, and socio-economic impact and feasibility studies are needed. Major impact will only be visible if many fish farmers in the region began to use it, or if monitoring and sanctions were being enforced and/or an incentive system established. Then the technique could become valuable. So far, there is no monitoring of effluent quality, and the cheapest and easiest way to discard untreated effluent is simply to channel it back into the lake (Table 1.3).

1.4 Adapted livestock management

Other examples of a combination of agricultural production (here livestock) and sustainable use of natural environment preventing its overuse are related to:

- improving livestock management by additional fodder production on natural and semi-natural areas, and
- improving grazing management

Grazing and fodder management in Madagascar

Samata fodder production and improving rangeland areas in Madagascar

context: livestock herders in the Mahafaly plateau region face seasonal water and forage shortage, epizootic diseases and an increasing number of livestock raids

problem: privatization, overexploitation of natural samata vegetation (open access) due to changing herding patterns influenced by increasing droughts and insecurity problems

solution: fodder production (samata nurseries and transplantation), better pruning practices that enable regrowth of trees (sustainable harvesting protecting samata stocks)

message: it is often best to try to strengthen indigenous systems that have worked in the past rather than seeking exotic remedies: in this case the assisted propagation of native fodder trees

On the semi-arid Mahafaly plateau region in south-west Madagascar, the local agro-pastoralist population rely strongly on livestock keeping (Figures 1.49 and 1.50). Possibly related to ongoing climate change with shorter rainy seasons and more droughts as well as risks of cattle raids on the plateau, the return of the herds to the coastal plain tends to start earlier each year (Goetter 2016). As a result, the pressure on the natural vegetation by livestock increases in the coastal plain (Feldt and Schlecht 2016).

During the dry season, the livestock keepers use the cut branches of a tree locally named 'samata' (*Euphorbia stenoclada*), an evergreen succulent, for feeding their animals, especially their zebu cattle (Feldt 2015) (Figure 1.51).

Figure 1.50: Zebu cattle grazing in the plateau area, Madagascar. (Johanna Goetter)

Figure 1.51: Feeding of samata (Euphorbia stenoclada) to zebu cattle in the coastal plain area, Madagascar. (Johanna Goetter)

Figure 1.52: Undisturbed samata (*Euphorbia stenoclada*) stand. (Johanna Goetter)

Figure 1.53: A degraded samata stand, Madagascar. (Johanna Goetter)

Samata trees used to be the dominant species of the shrubland around the coastal villages, but overexploitation and unsustainable cutting practices do not allow the trees to recover completely, and may even lead to their death (Figures 1.52 and 1.53). On 70 observed plots with different distances to the next village (up to 2.5 km) the average mortality rates of trees utilised in this way were between 13 – 22%, with the highest rates close to the village (Ahlers 2014, Goetter et al. 2015a). Today, many open access stocks of *samata* in the coastal plain have been privatized by individual users, especially the ones closer to the villages. As a consequence, the remaining open access stocks are heavily used and thus degraded, while the pressure on private stocks is much lower (Goetter and Neudert 2016). *Samata* also seem to suffer from the changing rainfall patterns, which result in decreased growth rates.

To alleviate overexploitation of the natural dry season fodder tree samata in the coastal plain, different methods of artificial propagation by cuttings and via germination of seeds were tested. In a nursery, cuttings and seeds were grown under different conditions regarding the substrate (red soil, white sand, calcareous soil) and shade versus sun. Cuttings were either treated or not treated with the hormone Aib (alpha amino-iso-butryc acid, 0-500 mg/l). For the germination experiment, different seed treatments were applied: soaking with distilled/ boiling water, treated with sulfuric acid, and/or seed scarification.

The testing of different methods of artificial propagation of *Euphorbia stenoclada* gave the following results: The best seed germination rates were observed for non-treated seeds (80%), followed by those treated/ soaked in distilled water before planting (67.5%). For cuttings, the experiment showed 100% mortality of cuttings planted under the shade. The best performance was achieved with cuttings raised in the sun, not treated by hormones and placed in white sand, which represents the natural conditions of the region (90% survival after 5 month). Cuttings under these conditions also showed better survival rates and growth in comparison to non-treated seeds (Figures 1.54 and 1.55).

In conclusion, propagation with cuttings is the preferred method. It is also technically much easier to apply as there is no need for treatment of seeds and seedlings. As a consequence, several local farming communities were trained in the vegetative propagation method, and small tree nurseries were established together with local communities and schools (Figures 1.56 and 1.57, see Technology 'Samata propagation' page 227 and Video).

Besides the cultivation of samata, recommendations were developed for sustainable harvesting of samata trees in the form of culturally-adapted comic strips (see Approach 'Comic style environmental awareness' page 235). The new practice was widely adopted by the local population (adoption rate 80%).

Figure 1.54: Survival rate of young E. *stenoclada* trees from seedlings and cuttings, Madagascar (n=20 each). (Herinavalona Rabemirinra)

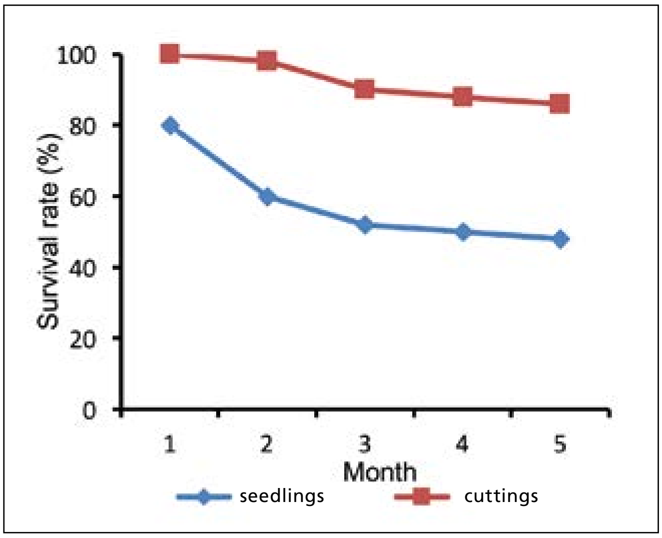


Figure 1.55: Growth of young E. *stenoclada* trees from seedlings and cuttings, Madagascar (n=20 each). (Herinavalona Rabemirinra)

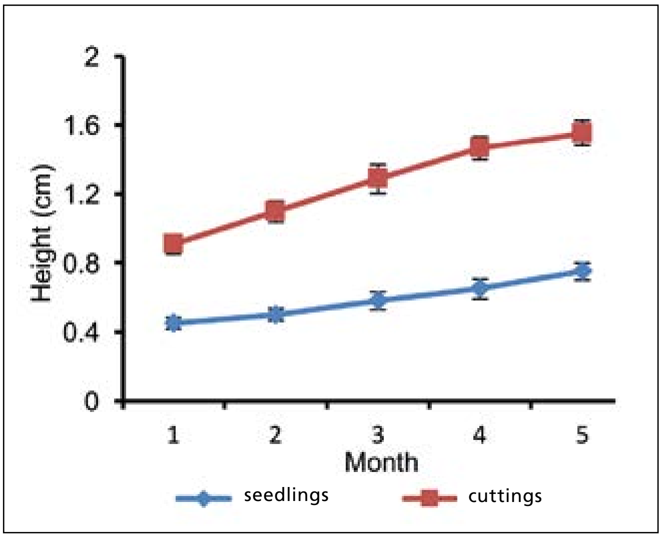


Figure 1.56: Workshop on propagation of *samata* held for the local population in the research camp of the University of Hamburg, Madagascar. (Corina Müller)

Figure 1.57: Planting of a rooted *samata* cutting from the first community nursery in the village of Ampotaka, Madagascar. (Yedidya Ratovonamana)

Changing grazing management in the *Caatinga* Brazil

Grazing management in the *Caatinga*, Brazil

context: degradation of the dry forest *Caatinga* ecosystem/ natural *Caatinga* woodlands

problem: overgrazing by goats and donkeys, no controlled grazing management and additional overexploitation for firewood, charcoal and timber

solutions: rotational grazing/ zoning, conservation/ protected areas, more organized herding and choice of livestock, cultivation of fodder crop, other sources for firewood and charcoal: management of an invasive species as well as coconut shells (waste)

message: degradation of forest is as serious a problem as deforestation in many parts of the world: apart from self-imposed community rules and regulations, there are several tried and tested technical methods of taking pressure off the forest

In the São Francisco River Basin, Brazil, overgrazing and browsing by ruminants (mainly goats, sheep and cattle, but also feral donkeys) is leading to degradation of the dry forest *Caatinga* ecosystem. So far, there is no overall grazing/ browsing management plan (for goats, sheep, or cattle), a low level of cooperative practice (and willingness to do so), limited economic resources of smallholders, and lack of knowledge of innovative approaches and technologies.

Solutions to be considered are rotational grazing (strategic resting of areas to regrow and regenerate), effectively fencing-off either livestock or agricultural plots and conservation/ protected areas. Other solutions are cultivation of fodder crops, and the use of crop by-products, or understorey grazing in irrigated coconut or fruit tree plots. Division of grazing land into zones, including conservation zones, and zone-wise rotation of pasture land to avoid uncontrolled overgrazing of *Caatinga* dry forest vegetation needs to be discussed and decided upon at higher administrative and political levels – since zoning needs enforcement for its implementation if there is no community cooperation. Another option that is currently preferred by consumers and land users is switching from goats to sheep. Goats are known to be selective grazers, but mainly browsers, and thus have an advantage. They can derive a much more nutrient-dense diet from harsh vegetation resources than sheep or cattle are able to. The often-cited damage caused by goats only occurs if grazing pressure is much too high. Sheep are basically grazers, in comparison they are less able to make use of natural bush or tree vegetation, and primarily graze the understorey, the grasses and forbs. Sheep are more easily managed than goats, and well-suited to an organized grazing regime that could support sustainable use of the *Caatinga*. Nevertheless, goats, besides their specific adaptation to climate and feed resources, have a high cultural status in the region and goat meat is much appreciated by the local population. However both species have pros and cons. Integrated crop-livestock management

Figure 1.58: Boxplot of lizard species richness showing significant higher species richness in *macambira* than in *Caatinga* vegetation. (Maike Guschal)

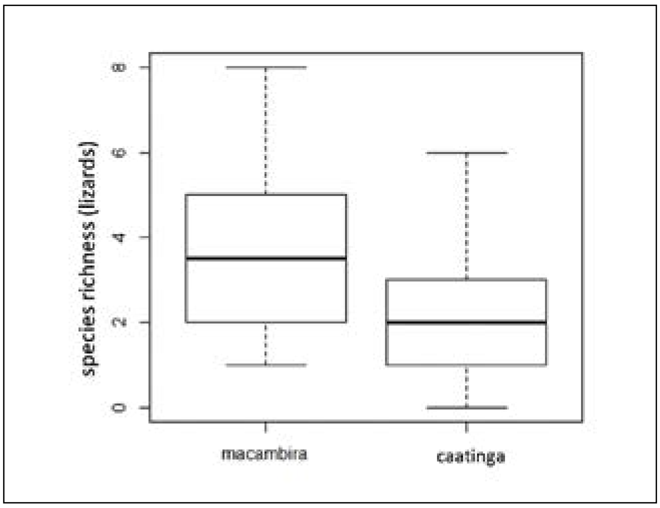


Figure 1.59: Distance between patches of natural aggregation of *macambira* turned out to be a significant explanatory variable for species richness. Patches next to other patches showed higher species richness than isolated patches in *Caatinga*, Brazil. (Maike Guschal)

could reduce the pressure on *Caatinga* vegetation by allowing small ruminants to feed on crop by-products or residues. Corralling of animals overnight has additional benefits because it concentrates manure, which can be used to fertilize soils.

The mix of patches of pasture with shrubs and trees with deeper roots produces higher soil biodiversity that can be beneficial in plant adaption to different weather conditions. From a conservation perspective, any change or decline in biodiversity is bad. However, from a livelihoods perspective, people have needs that create a footprint. From a sustainable use perspective, the two goals need to be balanced. A way to preserve native vegetation such as macambira (*Encholirium spectabile*) – which is also important to protect tree seedlings, small fauna, as well as ground-breeding birds – is by selective cutting, that is sparing well-connected large patches and only cutting, when really needed, smaller patches which are distant (Figures 1.58 and 1.59; Guschal et al. in preparation).

1.5 Managing natural and semi-natural systems

Expansion of intensified use or conversion of marginally suitable, and so far extensively used, land is increasing in many parts of the world, while simultaneously in some regions extensification is taking place. Both developments mean a challenge for future land management: preventing overuse of natural systems by developing an integrated mix of protection, sustainable use and extensive agricultural production when population pressure threatens the overuse of these semi-natural or still pristine ecosystems. On the other hand, in areas abandoned by intensive agriculture, new management opportunities arise or new ecosystems develop. Both situations pose new challenges and opportunities for sustainable land use and management practices to keep livelihoods and biodiversity/ ecosystems in a healthy balance and to make best use of synergies.

Improved production on land assigned for intensified, but sustainable, agricultural use reduces the pressure on other areas currently under extensive use: namely semi-natural or natural land, and it means that these systems can be kept intact.

In the following integrated management of forests and non-forest products are addressed at the local level:
- *Caatinga* ecosystems, Brazil
- Protection of wild yam in Madagascar
- Reducing pressure on forests in Madagascar

Figure 1.60: Large *macambira* group in a well preserved *Caatinga* area, Brazil. (Marianna Siegmund-Schultze)

New strategies for the use of *Caatinga* dry forests in Brazil

***Caatinga* forest/ woodland in Brazil**
context: overuse of *Caatinga* woodlands (slow recovery), use of material for households (building and fuel), conversion into cropping and overgrazing
problem: soil erosion by wind, overgrazing and excessive extraction of plant material, birds and game lead to loss of biodiversity
solutions: sustainable use strategies for native species especially *umbuzeiro* trees within and outside of their natural environment; protect existing and establish new conservation areas (network of conservation areas)
message: important natural systems (such as the *Caatinga* forests of Brazil) need to be maintained as far as possible: protection is one option but there are also possibilities of deflecting attention from the forest by encouraging planting of useful tree species on farms and elsewhere

In the semi-arid north-east region of Brazil in the São Francisco Basin, removing the slow growing natural vegetation of the *Caatinga* forest for human use renders the soil susceptible to erosion by wind and water. *Caatinga* means 'white forest' with small thorn trees (seldom taller than 6 m) that shed their leaves seasonally. The understorey is mainly composed by bromeliads, small cacti, grasses and annual plants (Figure 1.60).

Water scarcity and droughts, as well as decades of overexploitation of trees, is triggering stress on both floral and faunal biodiversity, especially in the natural system of the *Caatinga* dry forest. Important species are the native Brazil plum called *umbuzeiro* (*Spondias tuberosa*) and a bromeliad locally termed *macambira* (*Encholirium spectabile*), which helps to hinder soil erosion. Leaves of *macambira* are used to make a type of bread, and when burned it is used as cattle feed.

Using *Caatinga* and sustaining its services including productivity in the long-term needs a sensitive approach, avoiding overgrazing and excessive extraction of plant material, and birds and game that form part of the overall ecosystem. Approximately half of the total *Caatinga* area has already been overgrazed or converted to other uses. *Caatinga* use comprises browsing and grazing by animals (livestock and feral donkeys), cutting wood for fuel and charcoal (to provide fuel for cooking, bakeries and other industries), for construction and for animal fodder.

In the *Caatinga* dry forests, *macambira* is an important host for amphibians, birds and bees, and protects seedlings such as the young and vulnerable *umbuzeiro* tree. Scarce fodder, especially during droughts, leads to the cutting of trees and other plants as forage, thus reducing cover and slowing regeneration of dry forest. Another difficulty is the absence of a control mechanism for conservation areas, which are easily invaded either by landless people seeking farmland for themselves, or residents of the area looking for forest products. The result is, instead of conservation, degraded forest through slashing, cutting, browsing and collecting forest produce. Furthermore, conversion of natural habitats into cropland leads to increased pressure on the natural vegetation. Especially in the drier and drought-prone semi-arid areas, this is a risky development. Projections of different socio-economic and climate scenarios (SRES) show that a further increase of cropland is highly probable at the expense of pasture and natural vegetation (Figures 1.61 and 1.62).

The average of four future development scenarios projected a similar picture: (Figure 1.61), pasture (extensive) and natural vegetation cover will decline and crop land will increase, in which fodder

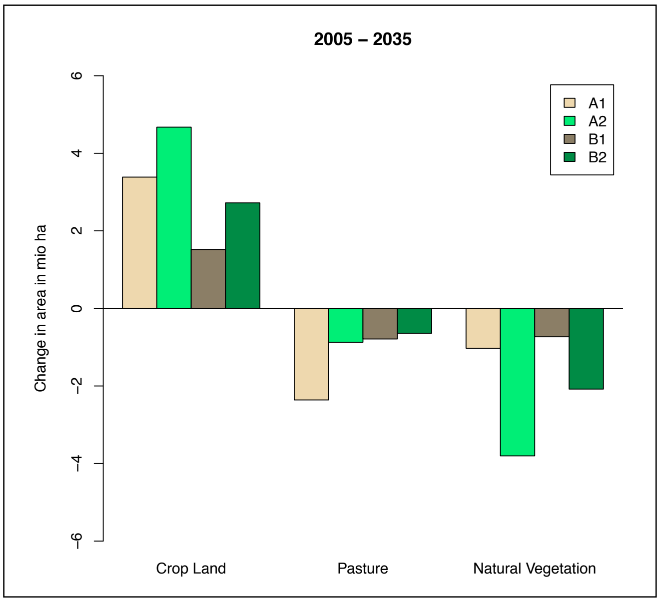


Figure 1.61: Projected change in land use area in the São Francisco River Basin, Brazil in million hectares from 2005 to 2035 of the four socio-economic and climate scenarios (SRES: A1, A2, B1, B2). (Biewald et al. 2014, based on Nakicenovic et al. 2014)

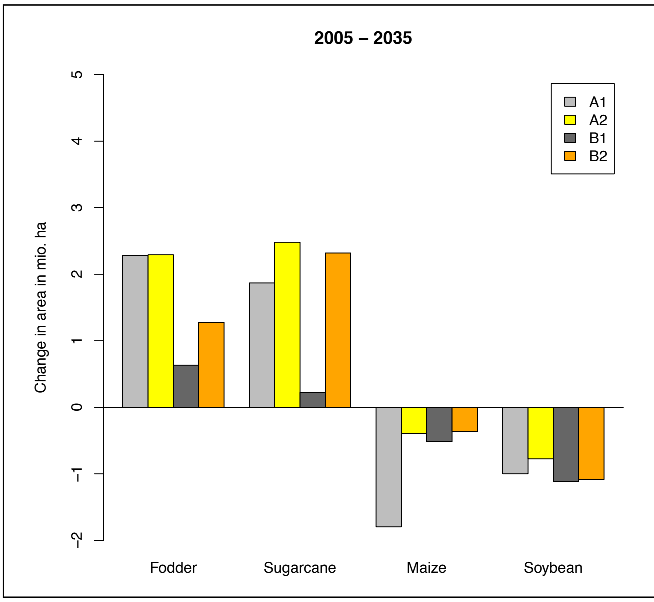


Figure 1.62: Projected change in cropland area for fodder, sugar cane, maize and soybean in the São Francisco River Basin, Brazil in Mio ha from 2005 to 2035 of the four socio-economic and climate scenarios (SRES: A1, A2, B1, B2). (Anne Biewald)

(intensive) and sugar cane will be on the up, in comparison to decreasing areas of maize and soybean (Figure 1.62). Sugar cane is very controversial because of its high water demand and use as a biofuel crop. Fodder is also questioned because it favours less efficient meat diets instead of directly securing basic human food needs.

The most obvious solution to reduce pressure on, and conserve, natural systems in the São Francisco River Basin is the protection of already existing, and the establishment of new, conservation areas. The development of detailed species inventories in different areas based on scientific biodiversity monitoring support the establishment and recognition of conservation areas for *Caatinga*, including *umbuzeiro* tree regeneration areas. The mere establishment of conservation areas is, however, not effective if there is no clear and realistic management and monitoring plan – and ensuring that the plan is followed and put into action. Keeping people and livestock out of an area is a demanding task – requiring skilled and committed personnel, fences, compensation payments, and alternative living and working options for the riparian dwellers.

An alternative to increased conversion to irrigation intensive agricultural production is a mixed strategy of small and medium-scale production opportunities, which are well-adapted to the local conditions, with sustainable use of the natural environments that surround those production areas. Rainfed agriculture is very risky, and seldom successful in the studied semi-arid area of the São Francisco Basin. Almost all cropland farmers have access to at least partial irrigation options, for instance small reservoirs, which dry out from time to time. In order to reduce dependency on irrigation, a common and well-adapted tree species, *Spondias tuberosa* (*umbuzeiro*), is being promoted. Active management and umbuziero tree planting would regenerate the tree population, and increase the production base for the use of the tree's fruits. *Umbuzeiro* is a multi-purpose tree, which produces fruits for people and livestock, fresh and dry leaves as a feed for goats and sheep, stores water in the root system, offers shade and has a cultural connotation.

Sustainable use strategies for the *umbuzeiro* tree should provide an incentive to maintain the native vegetation, and at the same time improve income opportunities for small-scale family farming (Figure 1.63). It can be established within irrigation projects as well as outside in *Caatinga* areas used for grazing.

Leaving indigenous vegetation that protects naturally germinated tree seedlings has multiple advantages. One of them is biological pest control (see Technology 'Biological pest control page 171 and Video). Studies in smallholder public irrigation schemes have shown that yields of crops did not increase with herbicide application, suggesting that farmers can refrain from using herbicides and instead rely on the natural enemies of the pests that live in the vegetation of the understorey and in field margins (Cierjacks et al. 2016). Amphibians and reptiles that live in the understorey can feed on insects considered pests, such as locust, caterpillars and beetles. An advantage is that an herbaceous layer in a tree plantation can be grazed mainly by sheep, giving a dual advantage: by producing animals and simultaneously maintaining the weed biomass at an acceptable level. Moreover, organic fertilizer alone (such as sheep or goat manure) led to similar yields of banana and coconut as application of mineral fertilizer (Cierjacks et al. 2016). Hence, farmers who have access to sufficient manure can refrain from buying and applying mineral fertilizer.

Figure 1.63: *Umbuzeiro* tree in the *Caatinga,* Brazil with heavily grazed understorey. (Marianna Siegmund-Schultze)

Protecting natural vegetation in Madagascar

Managing wild yams and tamarind trees in the savannah of Madagascar

context: overuse and unsustainable collection of non-timber foresproducts (NTFP) in natural habitats needed to ensure food security and health care

problem: population pressure and erosion of traditional taboos leading to overuse of yams and tamarind as supplementary food, medicine and for charcoal production

solutions:
– awareness-raising for sustainable harvesting of yams
– cultivation of yams (with different results on different soil types)
– use alternative tree species than tamarind for charcoal production
– develop tamarind plantations in villages and better processing for food

message: protect natural biodiversity from pressure/ overuse by developing alternatives and sustainable use strategies: however awareness-raising is key

Wild yam (*Dioscorea* spp.), medicinal plants and tamarind (*Tamarindus indica* L.) are important non-timber forest products (NTFP) in the Mahafaly region of SW Madagascar. They are frequently collected from natural habitats, and used in various ways by the local people to improve food security and health care. Yam is mostly consumed in addition to the daily staple of cassava and maize. However, yam species distribution models and maps showed that the population of wild yam is scarce, and mostly located in restricted areas of open and dry spiny forest where overharvesting combined with unsustainable harvest methods threatens the wild yam population (Andriamparany et al. 2015). The multipurpose tamarind trees are mainly used as supplementary food (their fruits are consumed), but also for medicinal purposes – and for traditional ceremonies as they are considered sacred. The traditional belief system, which was fundamental to sacred tree conservation, appears to be gradually eroding and local people tend now to ignore taboos to log tamarind trees for charcoal production, and slash and burn agriculture. Today, tamarinds belong to the preferred tree species for charcoal production (due to their high calorific value), resulting in a significant density and biomass decline on the plateau during the past 10 years (Ranaivoson et al. 2015; Figures 1.64 and 1.65).

To prevent further degradation and overuse, awareness-raising regarding sustainable collection methods of forest products (wild yam and medical plants) is strongly recommended. After harvesting wild yam tubers, collectors should be encouraged to replant the upper part of the tubers in the soil. This action will not only ensure the regeneration of tubers, but will also reduce soil degradation due to the holes left after harvesting which capture runoff and sediment.

Figure 1.65: Changes in the density of tamarinds on the Mahafaly Plateau and Littoral area, Madagascar from 2004/ 2005 to 2012. (Tahiry Ranaivoson)

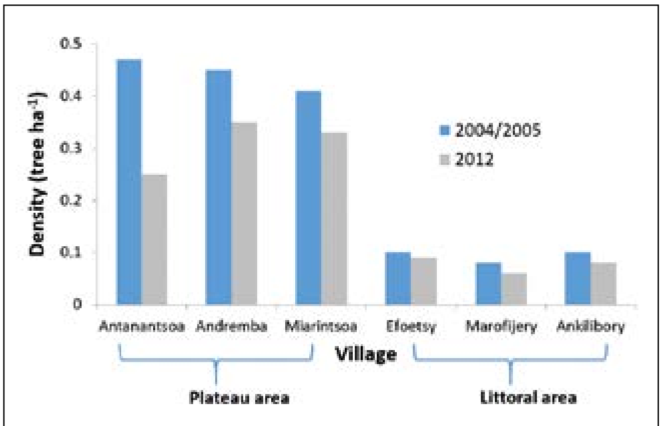


Figure 1.64: Logged tamarind tree for charcoal production. (Tahiry Ranaivoson)

To easily communicate these recommendations for sustainable harvesting of wild yam, comic-style illustrations of visual narratives were designed, showing two contrasting scenarios of sustainable – and unsustainable – harvesting techniques (Figure 1.66, see Approach 'Comic style environmental awareness' page 235).

In order to decrease the pressure on wild yam (Dioscorea spp.) and to ensure the in-situ conservation of wild germplasm, cultivation of yam (cultivated and wild species) is strongly recommended on the Mahafaly Plateau. Vegetative regeneration with the upper part of the tuber, and mini-sets were tested in the field. The mini-set technique involves the cutting of 'mother' seed tubers into small sets/ pieces of 25-100 g (mini-sets) with a sufficient periderm/ skin from which sprouting occurs after replanting. The differences between tuber and mini-set regeneration were not significant. However, sprouting performance significantly differed between soil types and wild yam species. The use of locally available manure has been reported to increase the yield of cultivated and wild yam species (Andriamparany 2015).

In order to reduce the pressure on the tamarind, other more abundant tree species with rapid growth such as Acacia bellula in the coastal zone and Albizia polyphylla on the plateau are recommended for charcoal production. Traditional techniques of charcoal production yield 12 – 35 % of the original biomass as charcoal, which is relatively high, but leaves room for improvement. In addition, the establishment of tamarind tree plantations in villages as well as enhancing its contribution to peoples' diet through the promotion of more elaborate processing and marketing of local products will help to protect wild tamarind.

Reducing pressure on forests in Madagascar

Managing forests and non-timber forest products of Madagascar

context: increased pressure on forests resources and land use and land cover change, slash and burn cultivation due to population growth and low productivity

problem: deforestation and overuse of natural vegetation thus scarcity of food and other products, which are collected from the forests (vicious cycle)

solution: cultivation by intensifying and making other land use systems more productive and efficient, develop concepts for attractive sustainable forest use, restoration and reforestation activities on abandoned farmlands, community-based sustainable forest management

message: pressure on forests can only be relieved by increasing production elsewhere – including agroforestry on farms

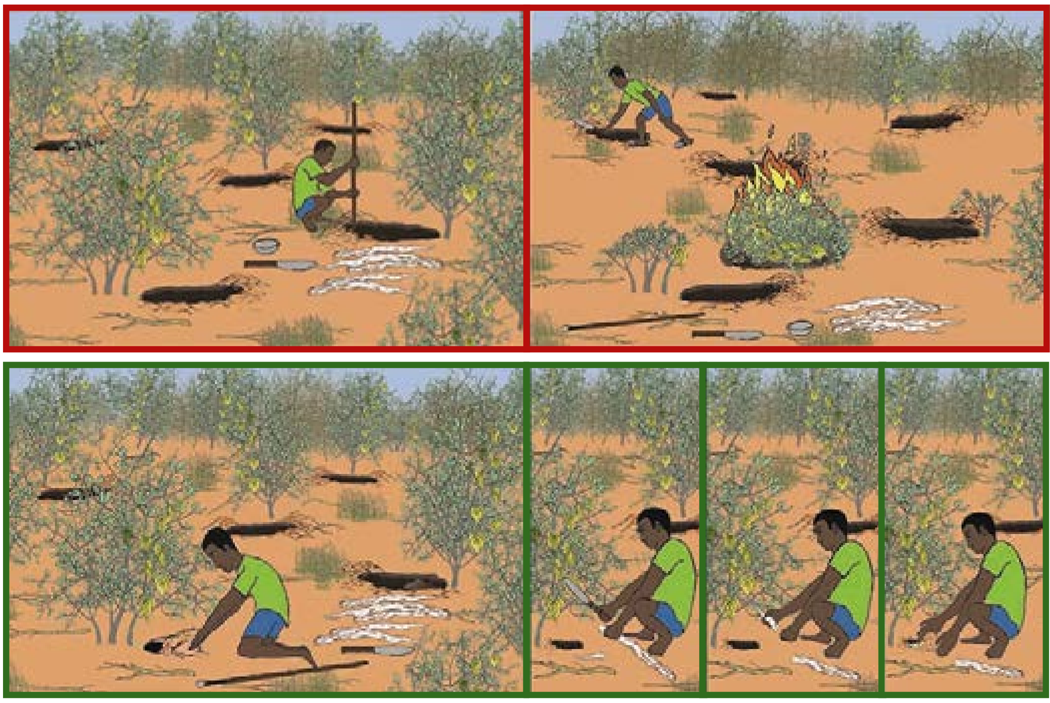


Figure 1.66: A scene from the comic showing an unsustainable harvesting technique (top, red) and a recommended sustainable harvesting technique of wild yam, Madagascar (bottom, green). (David Weiss)

In the Mahafaly region of south-western Madagascar, ongoing population growth, increasing aridity and unsustainable land use techniques have increased the pressure on forests resources and triggered land use and land cover changes (LULCC) (Figure 1.67). Over the past 40 years, forest losses amounted to 45% and have led to increasing savannah formation and forest fragmentation.

Deforestation was greatest in remote locations, and near to small settlements that are poorly connected to infrastructure and main markets, and are relatively young. Major direct drivers are slash and burn agriculture (Figure 1.68) and charcoal production (Figure 1.69) which play an important role in income generation. Overexploitation of wild species and wood resources, as well as grazing and browsing, may further contribute to forest fragmentation processes (Brinkmann et al. 2014). The loss of natural forests directly affects peoples' livelihoods since smallholder farmers rely on natural forest products to sustain their daily needs, especially during periods of crop failures. These are fall-back resources for human nutrition and natural medicines.

The Malagasy farmers are aware that slash and burn agriculture destroys their forest resources. However, they will most likely continue to practice it as long as income alternatives and other promising crop cultivation techniques are lacking – and open space to grab land is available. Thus, one potential solution to deforestation is to provide local communities alternatives to slash and burn cultivation by intensifying production on existing land, and making other land use systems more efficient (improving soil fertility; using drought resistant crop varieties etc.). This will reduce the pressure to further convert forest into agricultural use.

Additionally, making more attractive the sustainable use of the forest and of its multiple services has the potential to reduce further deforestation at the landscape level. To achieve this, community-based sustainable forest management is often considered a promising approach, as it not only increases the value of forests for the local population by providing wood and NTFPs, but also contributes to the long-term conservation of the forest ecosystem and its biodiversity. However, results show that the available standing wood stock and growth rates of tree species used for construction, housing or charcoal production are very low in the dry forest ecosystem in the area (not only compared to tropical rain forests, but also compared to tropical dry forests in other regions). This poses an obstacle to the successful implementation of sustainable forest management in the study region. The situation can be improved through the application of silvicultural techniques to increase growth rates, such as enrichment planting of valuable tree species, or thinning of the forest to reduce competition for trees that are selected for future use. Further, forest restoration and reforestation activities on abandoned farmlands are recommended to reduce the pressure on remaining natural forests.

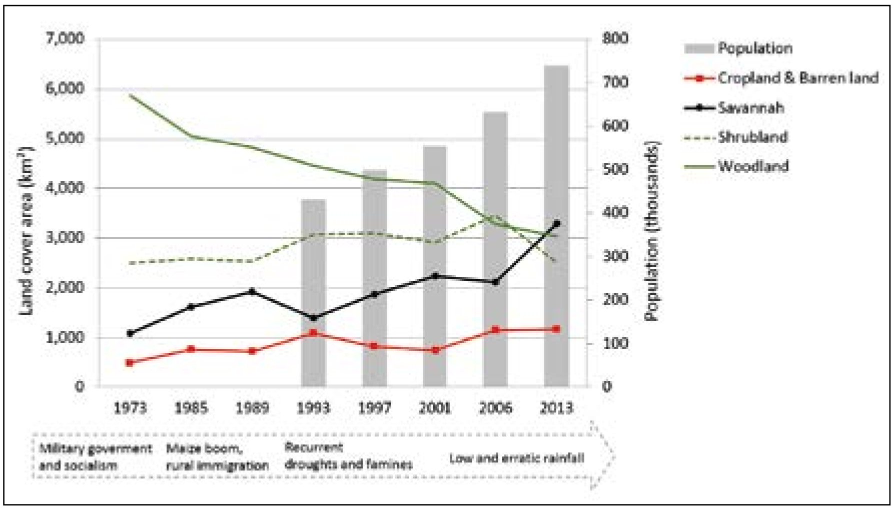


Figure 1.67: General land cover change (LCC) trends from 1973 to 2013 for the whole study region and population trends from 1993 to 2013 for the three districts (Betioky-Sud, Toliara II and Ampanihy in SW Madagascar) (Brinkmann et al. 2014).

Figure 1.68: Slash and burn for cultivating maize on the Mahafaly plateau. (Katja Brinkmann)

Figure 1.69: Deforestation driver: charcoal production on the Mahafaly plateau. (Tahiry Ranaivoson)

Conclusions

The challenges addressed by research at the local level are related to ongoing or increasing land degradation of soil, water and vegetation.

Soil fertility decline due to:

- Loss of soil cover, loss of soil organic matter, decline in soil structure – as a consequence of soil erosion by water;
- Agricultural intensification with lack of organic fertilization and amendments, a significant increase in inorganic fertilizer application, a simplification or abandonment of crop rotations, and a trend towards growing more cereal crops which are vulnerable to losing their productivity due to nutrient mining; and
- Soil salinization and pollution through intensification in conventional agricultural systems, including irrigation.

Growing water stress due to:

- Increasing demands especially on irrigation water; climate change already affecting rainfall and irrigation water availability;
- Recurrent drought and flood events, and non-adapted land use leading to the paradox that in the same place, at different times, there can be either too little or too much water;
- Climate change (rainfall patterns and amounts) and climate extremes make efficient use of rainwater now, and for the future, an increasingly pressing issue;
- Inefficient rainfed and irrigation water use;
- Non-productive evaporation of rainfall or irrigated water without conservation measures: currently between 40-70% and this large loss is unrecognised (Figure 1.70); and
- Surface runoff is both loss of water *and* the main cause of land degradation by soil erosion: therefore, the need to manage water better in all zones.

Degrading vegetation and cover in natural, semi-natural systems:

- Increasing pressure on natural and semi-natural habitats threatening biodiversity and ecosystems.

Challenges and opportunities for rainfed agricultural systems at the local level

The challenges for land management in rainfed agriculture for soil, water and vegetation are as follows:

- First and foremost, the nexus between soil, water, and vegetation must be recognised and respected, and interventions should be aimed at addressing all of them.
- Making sure that land management does not degrade the natural resources of soil, water and vegetation, while maintaining ecosystem function and services at the heart of sustainable land management.
- Research results show impacts of different land management practices. Some of them lead to degradation of the vegetation, the soil and the water resources. Other practices illustrate the potential for improved land management through diversified mixed cropping, grazing and forest/ woodland systems in which land users seek a balance between low risk, stable production and practices with higher risks and potentially greater gains.

Opportunities and principles for land management in rainfed agriculture for soil, water and vegetation are as follows:

- Permanent high degree of cover protects the soil surface from heavy storms, and from exposure to the sun and wind. It thus protects the land from erosion and evaporation loss, and encourages water infiltration. Essential is maintenance of crop residues, mulching, rotation, intercropping and agroforestry (including nitrogen-fixing legumes), planting of adapted species (e.g. salt/ drought tolerant), conserving natural vegetation (e.g. forests, riparian forests). Cover is key, if not the key, to improved land and water management.
- Minimum soil disturbance by no-till or minimum tillage and direct seeding of crops: leaving more residue and green cover provides environments for enhanced soil biotic activity, and maintains more intact, interconnected pores, and better soil aggregates. Carbon dioxide (i.e. GHG) emissions are reduced. Improved soil nutrient and water-holding capacity, reduced pests and diseases results; increased farm income too – though there may be a need to adapt or replace current farm machinery.
- Soil amendments by manuring and composting, green manuring, additions of biochar and fertilizer are essential. These all help by building up soil organic matter (SOM) which aids soil structure and health, as well as fertility. Compost and manure help to close the nutrient cycle – and integrated crop-livestock management has a central role to play. Appropriate supplementation (of limiting nutrients) with inorganic fertilizers is often required. Another potential is trapping of sediments and nutrients in areas with soil and wind erosion.
- Adapted irrigation water management for improved drainage, salt flushing and water use efficiency can help in specific areas.
- Cultivation and selection of the most adapted and appropriate crops: drought tolerant, salinity tolerant, adapted to available nutrient levels and the local soil properties. Avoiding depletion of soil fertility and water resources, or the diversity of the surrounding vegetation.

- Decreased land degradation – especially the loss of surface water and erosion and downstream sedimentation by applying the above principles and (where necessary) utilising cross-slope barriers with vegetative or structural barriers trapping sediments and nutrients.
- Harvest water in all systems from small-scale subsistence farming to commercial crop production. Water harvesting and storage in the soil during times of rainfall excess and using during times of water deficits has great potential for further application especially in arid and semi-arid environments. But even in the humid climates periods of water shortage occur and water harvesting practices play a crucial role in bridging these dry spells or seasons.
- Even though not explicitly proven by the research projects, many promising land management practices improve the microclimate by protecting soils and water resources from exposure to wind and the sun. They balance extreme temperatures and reduce exposure of the natural resources to radiation, wind and temperature stress.

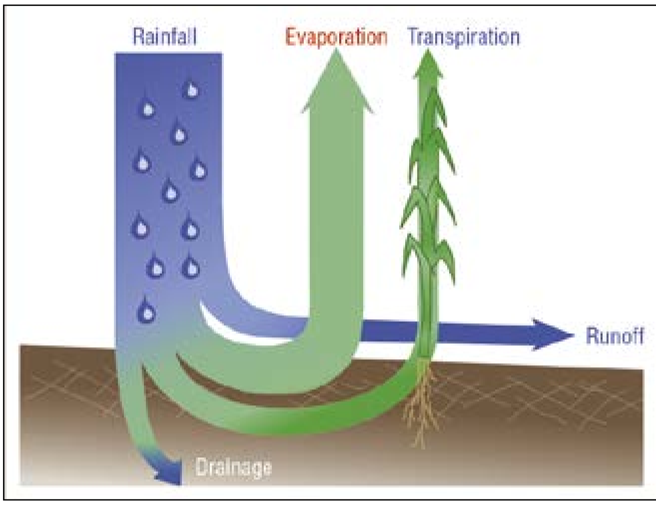


Figure 1.70: Productive water (transpiration) and water losses (evaporation and runoff) without water conserving measures in drylands. (Liniger et al. 2011)

Water – the limiting resource in irrigated agriculture – challenges and opportunities

In areas with low and insecure rainfall, irrigation continues to play an important role in increasing crop production and food supply. Currently globally 20% of the agricultural land is under irrigation and produces 40% of the total agricultural production. However, freshwater withdrawals for irrigated agriculture is about 70% of total freshwater use (FAO 2014). Water scarcity, for irrigated crop production is a common challenge.

The challenges for irrigated agriculture are:
- Water already is, and will become, more and more a limiting factor in agricultural production, be it rainfed or irrigated. There are conflicts over water between different users and uses (agriculture, industrial and domestic). Already ongoing over-exploitation of the water resources will have serious repercussions and drawbacks.
- Climate change and climate extremes are likely to affect water availability with increasing droughts, dry spells, increased rainstorms followed by expanded dry periods leading to increasing water scarcity and hence decreasing crop yields and risk of crop failures – as well as availability of water for hydropower generation and other uses.
- Coupled with water scarcity and current irrigation practices is the severe expansion and severity of salinization in the soil, and also of surface and groundwater resources. Intrusions of salt water into freshwater aquifers is a global and growing threat to freshwater supplies of cities and well as irrigation supplies.

The opportunities and principles for irrigated agriculture are:
- Due to water scarcity and high investment costs for irrigation, the first principle is related to non-irrigated areas to make best use through rainwater and adopt water conserving practices in order to reduce the demand for further irrigation water.
- Harvest water wherever possible. Water storage and harvesting has great potential for further application especially in arid and semi-arid environments. Multiple claims on the use of reservoir water needs strong management skills – especially balancing the claims for hydropower, irrigation and ecological flows.
- The following principles are additional and related to irrigated small, and large-scale, land management:
  - sprinkler – or even drip irrigation – rather than flood irrigation
  - improved timing of irrigation
  - choice of drought resistant/ tolerant or water-efficient crops: sugar cane is controversial in Brazil because of its water consumption and use as biofuel
  - consider carefully intensive production of cotton in arid areas because of its many trade-offs with water availability and salinization
  - re-use drainage water
  - introduce water quotas/ pricing to make water use more efficient, and by reducing demand, 'release' extra water becomes available for natural vegetation
  - adapt irrigation management to local soil and water conditions to avoid or decrease salinization

Integrated management of natural, semi-natural systems

The challenge is to sustain and improve livelihoods – but not at the expense of degradation and over-exploitation of natural and semi-natural ecosystems. This implies coping with the multiple demands for food and non-food production including biofuels, fodder to be supplied from natural forests, woodlands and grasslands.

The challenges are to:
- reduce deforestation and conversion of forests/ natural habitats into agricultural or urban land
- reduce wood extraction, and overexploitation of wild species
- avoid overexploitation for charcoal and fuelwood production
- limit overgrazing and overexploitation of natural vegetation by livestock
- manage the increased pressure on natural systems during the dry season and drought years to supply food, fodder, biofuel and timber and non-timber products

The opportunities and principles for the management of natural, semi-natural systems are to:
- reduce pressure on (semi-) natural systems by intensification of production on the current agricultural land
- build fodder banks and introduce multiplication of fodder plants
- introduce zoning, and rotational grazing
- integrate crop and livestock management
- value the natural environment and develop practices for its use and preservation
- develop alternative use and income generation by adding value to the semi-natural state of the land e.g. through ecotourism
- develop practices of careful management of semi-natural areas, trying to reconcile conservation and use
- integrate conservation/ production practices into ecosystems for better service provision, and combine with carbon sequestration: think 'multiple co-benefits'

CHAPTER 2

Landscape management – adapting to climate change

North Sea Germany, Hanspeter Liniger

Introduction

At the landscape or watershed level, different land uses and their management are combined and connected. This is often from a mountain top to the slopes and onto the valley or coastal shoreline, or within a watershed from the humid upstream mountain areas to the dryland areas or flood plains. Landscapes and watersheds can be small or relatively large, but always there are connections or dependencies between the different elements within. The most obvious example is water with its origins and supply from the upstream areas down to streams, rivers, lakes, swamps or the sea. The landscape level integrates various local land management practices and their impacts and interrelations. These landscapes can embrace contrasting natural environments (humid-arid, steep-flat) as well as the human population that inhabits and utilises them (farmers, pastoralists and other rural and urban dwellers).

Because of the environmental and human interactions, the challenges are to reduce the conflicts and damaging impacts arising from unsustainable land management within one part of the landscape and its impacts in the adjacent/ dependent part (off-site). Or, in a positive sense, the opportunities are to enhance synergies of local good land management of one group of land users in one area of the landscape with other land users and uses in other areas - or to compensate for negative impacts in one area by positive ones in the other, resulting in an overall positive impact.

Interactions and interdependence can be at different scales, between the same and different land use systems neighbouring each other or within a watershed or 'windshed' far apart, causing and/or being affected by major off-site impacts. Common connecting agents at the landscape level include water (watershed), wind ('windshed': including the area affected by winds and wind-transported elements such as dust, sand, soil, and pollutants), vegetation and natural corridors (forest strips, hedges, for animals like predators, etc.) for biodiversity and pest and disease management. As interactions between different land uses and users are even more prominent at landscape level/ scale than at the very local scale, they also become more complex, especially when it comes to the interaction between land users and land uses.

Strategies for production, climate change mitigation and adaptation, and preservation of ecosystems have to be integrated from local to regional, and from national to international scales to develop reliable and sustainable solutions. The 'water topic' naturally is most prominent in this chapter because the water cycle crosses scales, whereas soil (except for soil erosion by wind) and vegetation are less mobile.

Examples of these integrated strategies at the landscape level can be seen in three areas:

- River basin management
  The most prominent need for cooperation is in river basin management, dealing with multiple and often conflicting claims (hydropower, agriculture, industry, natural ecosystems and households) on water availability, multiple impacts on water quality under changes related to climate, but also demands for services within river basins or watersheds.
- Protection and use of riparian forests for ensuring water quality
  Riparian forests are, or should be, protected for their multiple effects (groundwater recharge, water quality improvement, preventing soil loss, biodiversity). Rivers transverse the whole landscape and thus, such riparian forests are important throughout. These ecosystem services (ESS) become especially visible in combination with adjacent crop cultivation – both rainfed and irrigated.
- Coastal zone management
  In coastal zones, different land uses have to be combined to sustainable land management (SLM) strategies especially in situations where a changing climate leads to rising sea levels and a change in the freshwater – saltwater balance. An important practice is preserving or restoring marine ecosystems as natural coastal protection.

Practices described in Chapter 1 are referenced here to show their effects on a larger scale, and in combination with other measures and land uses.

2.1 Land and water management in river basins

A river basin is the geographical area where all the runoff water is drained by a river and its tributaries and is conveyed to the same outlet. Land and water uses upstream affects water availability for downstream societies. Changing, and in most cases increasing, upstream and downstream claims on – and uses of – water are challenges for management. Additionally, land use changes might lead to higher runoff and risks for floods in the downstream areas and to droughts and desertification on the other hand. The challenge is to deal with both water scarcity and flash floods; both are likely to increase in frequency and severity with climate change.

The main drivers of change are increasing pressure from population growth, with ever greater demands for water, energy and food. The high complexity of the interaction between different water and land uses within a river basin, as well as the investigations into different scenarios of future development requires support from science – including integrated modelling methods. However, research often lacks resources as well as cooperation from various stakeholders and sectors involved in a river basin management – having different, and partly hidden, interests.

Four examples of land and water management in river basins are presented as follows:
- Water management in the Vu Gia Thu Bon (VGTB) River Basin in Central Vietnam
- Water management in the Okavango Basin and Delta
- Managing water scarcity and quality in the São Francisco River Basin, Brazil
- Measures to restore water-environment interactions, São Francisco River Basin, Brazil

Water management in the Vu Gia Thu Bon (VGTB) River Basin in Central Vietnam

Matching hydropower, irrigation, drinking water needs and protection of lowlands from salt water intrusion (Vietnam)

context: modification of the hydrological system through damming and diversion of river water for hydropower generation; increasing climate variability and climate change effects (less rain and uneven distribution); salt water intrusion due to lack of discharge from upstream; downstream water scarcity due to over-abstraction (irrigation and domestic water use)

problem:
– water scarcity in dry season for all users
– increasing risk of salt water intrusion affecting irrigation and domestic use

solution: model-based and integrated river basin management; facilitated dialogue/ platform; coordinated river basin water management to serve all needs in different seasons (mix of measures); adapted hydropower reservoir operation to downstream demand; improved water use efficiency and prevented salt water intrusion by mix of measures

message: solutions to fulfil multiple demands for the catchment's water resources can best be achieved by a mixture of decision-support based on scientifically sound system understanding and modelling and discussion platforms between stakeholders: both local and from the scientific community

Context

In tropical catchments e.g. of South East Asia, most attention is paid to flood risk management, although water shortage and droughts are the most frequent and devastating disasters in terms of economic losses (Navuth 2007; Adamson and Bird 2010; Geng et al. 2016; Terink et al. 2013). Catchment systems on the one hand are modified by various human interventions causing water scarcity, and on the other are exposed to frequent droughts. The Vu Gia Thu Bon River Basin (VGTB) in Central Vietnam is a heavily modified system due to hydropower development and operation as well as intensive, irrigated agriculture. Additionally, water scarcity in the VGTB River Basin is exacerbated by large-scale climatic variability, causing increasing meteorological and hydrological drought events, and increasingly uneven distribution of rainfall.

The river basin consists of two main river systems, comprising the Vu Gia in the northern part, and the Thu Bon river in the southern (Figure 2.1). The northern catchment of the Vu Gia is drier and smaller than the larger and wetter southern catchment of the Thu Bon. But the water demand in the lower reaches and delta of the Vu Gia is much higher than that of the Thu Bon, due to larger irrigation schemes in the delta and the city of Da Nang. Despite this imbalance, water is diverted from the Vu Gia river to the Thu Bon and several hydropower dams in the upper catchment are influencing water discharge in the river (Figure 2.1).

The Vu Gia-Thu Bon River Basin is ranked fourth in Vietnam for potential hydropower generation capacity after the Da, Dong Nai and Se San river systems. The total generation of hydropower was 3,985 TWh in 2013 (Ministry of Industry and Trade 2014). If compared to an average consumption of 1415 KWh per capita at the country level, the total electricity produced by hydropower in the VGTB outweighs the estimated consumption (total 3.5 TWh).

In 2013, six large-scale hydropower plants, the A Vuong, Song Tranh 2, Song Con 2, Song Bung 2, and Song Bung 6, came into operation. In addition, the DakMi 4 hydropower station has been operating since 2012, and is diverting water from the Vu Gia to the Thu Bon to increase its efficiency (Figure 2.1). The diversion reduces Vu Gia's discharge to the lower areas of the basin, in which large areas of irrigated agriculture and Da Nang city are situated. Another diversion at the Quang Hue River in the lowlands was established in the 1980s to prevent flooding of the city of Da Nang. It still diverts water to the Thu Bon taking away water from the Vu Gia before it reaches the large irrigated areas and the city. In the dry season, and especially in times of drought, this leads to shortages in irrigation water and drinking water supply for the city of Da Nang. In addition, it further increases the problem of salt water intrusion in the Vu Gia.

Figure 2.2 shows the volume of water taken away from the Vu Gia river at Thanh My station due to hydropower operation upstream (see Figure 2.1). The dashed line shows the observed discharge volume during the dry season of 2013 (from 01 April to 01 September) while the upper black line indicates the natural discharge without hydropower impacts. Due to hydropower operation, the discharge in the dry season is reduced to about half.

Increasing water demand
From the demand side, water shortage is caused by increasing water demand for food, energy, tourism and industry due to population growth, urbanization and socioeconomic development.

So far, there is no drought risk regulation in Vietnam and this is compounded by a lack of information and research on drought impacts, frequency and characteristics. Hence, based on a complex assessment and a modelling framework, initial results related to drought characterization for the Vu-Gia sub-basin – as well as recommendations for appropriate management strategies – have been determined.

As shown in Figure 2.2 the impact of hydropower development upstream has reduced downstream dry season discharge of the Vu Gia river to about half (at times even to 40%) affecting the water supply of about 1.7 million residents and rice farmers. The potential impact of hydropower projects on downstream water availability was not discussed with downstream water users and other relevant stakeholders during the development of hydropower construction plans. This has directly led to water availability problems and conflicts, especially affecting the drinking water supply plant, Cao Do, of the city of Da Nang – and rice irrigation also. Hence, in order to improve the decision-making process and to solve the water scarcity problems in the region, the simulation results were discussed with the hydropower generators and the water users in the estuary.

General management recommendations for the decision-makers in management of the VGTB river basin are as follows:

- establishment of an independent platform for the stakeholders involved to become aware of the seasonal demand of all water users and to improve allocation;
- optimisation of hydropower/ reservoir operation based on multiple objectives (e.g. irrigation, floods, disaster management, and environmental flows);
- development of a drought management plan for the Vu Gia river to ensure adapted management of water resources;
- establishment of an early warning system, based on improved climate and discharge monitoring, especially in the upstream mountainous part; and
- improvement of the monitoring framework: establishing hydrometeorological stations, especially in the upstream part of the basin.

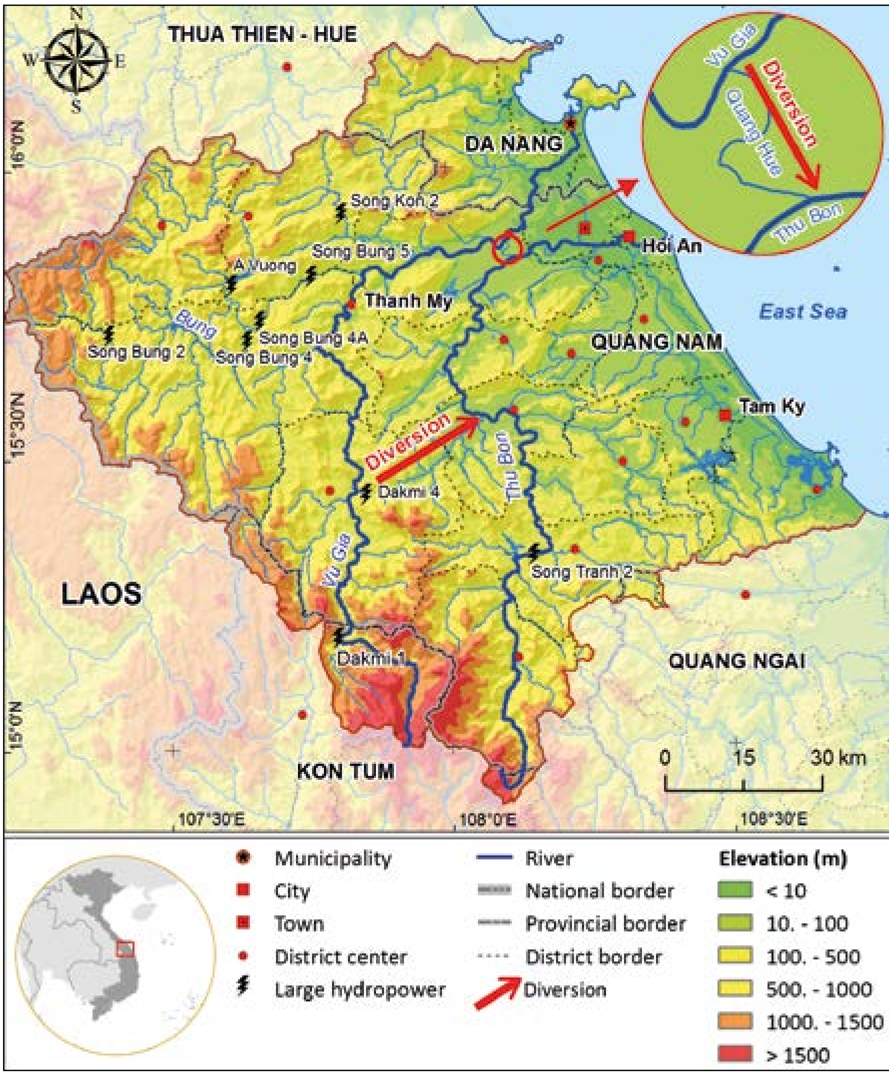


Figure 2.1: Topographical map of the VGTB river basin highlighting the hydropower plants/ reservoirs and the two diversions from Vu Gia to Thu Bon, Vietnam (Nauditt et al., 2016).

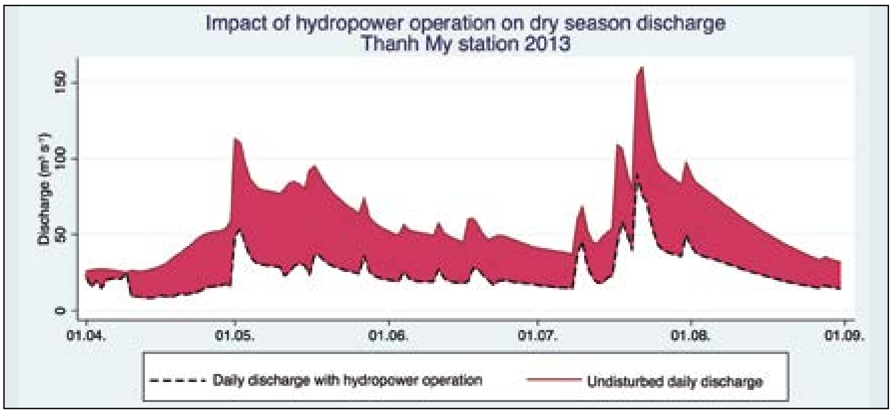


Figure 2.2: Impact of Dak Mi 4 Hydropower operation and the consequent diversion of water from Vu Gia to Thu Bon on the discharge of the Vu Gia river measured at Thanh My station, Vietnam at the border of the upland catchment to the delta region in 2013 (see also Figure 2.1) (Nauditt et al. 2016).

Figure 2.3: A temporary saltwater obstruction made of sand on the Vinh Dien River, Vietnam. These structures will be destroyed by the first floods of the wet season. (Trinh Quoc Viet)

Figure 2.4: Controlling drainage flows from paddy farms to reduce discharge of drainage water and reusing it for irrigation. This improves irrigation efficiency, and reduces the demand for irrigation water from the rivers – and does not deplete the river flow and thus hinders saltwater intrusion, Vietnam. (Trinh Quoc Viet)

The special case of salt water intrusion

Sea level rise, decreasing river flow to the delta region due to growing upstream damming and diversion for hydropower generation, as well as river water abstractions for rice irrigation, have led to a growing risk of saltwater intrusion during the dry season in the delta region.

The immediate challenges related to decreased dry season flows are:
- improper spatially and temporarily water allocation due to lack of effective cooperation among different water users, both up- and downstream;
- diminished flow of Vu Gia during the dry season, which cannot repel saltwater intrusion at the intakes of irrigation pumping stations, and urban water supply schemes;
- sea level rise and amplified tides increasing the intrusion of saltwater; and
- yield losses and problems with urban water supply during periods of saltwater intrusions.

Drought disasters in the VGTB River Basin estuary are essentially characterized by salinity intrusion. Saltwater intrusion is recognized as a severe threat to the local socio-economy in the populated VGTB estuary. Water above the salinity threshold of 1 parts per trillion (ppt) can enter up to 15 km landwards during dry periods. Values exceeding 0.1 g/l are a threat to drinking water, and consequently force the drinking water supply plant at Cau Do station (Figure 2.2) to stop their water abstractions from the Vu Gia main stream where it is located. For agriculture, the salt threshold of 1.0 g/l for irrigation is applied and when salinity in river water exceeds this value, pumping stations are turned off.

Currently existing measures to address this problem are:
- building temporary sandy saltwater obstruction dams during dry periods. These dams are destroyed during the first floods of the rainy season (Figure 2.3);
- operating the barrage system to facilitate discharge from upstream to push back salt water;
- reducing irrigation return flow, storing it and reusing it (Figure 2.4, see Technology 'Reuse of return flow in rice' page 271); and
- installing standby pumping stations further upstream, where they are not affected by salt water and can provide fresh water for the water treatment plant, Cau Do, that supplies water for the city of Da Nang.

In a modelling and scenario development exercise, the spatial and temporal salt water intrusion risk and the spatial vulnerability of different land users (irrigation schemes and settlements) was calculated (Viet, 2014).

The impact of saltwater intrusion on agricultural production in the VGTB lowlands was calculated through the application of a numerical model-based risk assessment framework. After model calibration, five modelled-based scenarios (Table 2.1) were run to simulate changes in salt water intrusion under different framework conditions:
- different conditions of river discharge from upstream;
- alterations in water use due to land use changes: required irrigation demand and domestic water use;
- changes through sea level rise;
- human intervention by adaptation measures.

Table 2.1: Scenarios for dry season river discharge to assess the risk of salt water intrusion in Thu Bon and of Vu Gia rivers, Vietnam.

No	Scenario (S)	Influencing factors			
		Discharge from upstream of Thu Bon and of Vu Gia (m^3/s) Baseline year 2005	**Water demand** for irrigation and for domestic use (m^3/s)	**Sea level rise**	**With/ without adaptation measures**
S1	Current state	Thu Bon: as in 2005 Vu Gia: as in 2005	irrigation as in 2005 domestic as in 2005	0 cm	without
S2	Mid-term without adaptation measures (~2030)	Thu Bon: as 2005 + 40 m^3/s Vu Gia: as 2005	irrigation as 2005 -1 m^3/s domestic as 2005 +1 m^3/s	+ 15 cm	without
S3	As scenario S2	As scenario S2	As scenario S2	+ 15 cm	with
S4	Long-term without adaptation measures (~2080)	As scenario S2	irrigation as 2005 -1 m^3/s domestic as 2005 +3 m^3/s	+ 50 cm	without
S5	As S4	As scenario S2	As scenario S4	+ 50 cm	with

The baseline is the discharge and water demand for irrigation water as measured in 2005 (a relatively dry year). The discharge of the Thu Bon river in Scenario 2-5 is increased by 40 m^3/s due to the operation of the DakMi 4 power plant and its diversion of water from the Vu Gia river. In the Vu Gia river this is calculated to be compensated for by the reservoirs operative after 2017. The changes in water demand in scenario 2-5 are based on the calculation of land use changes due to increasing expansion of cities into agricultural areas, which increases domestic use and decreases the demand for irrigation water. The adaptation measures incorporated in the model are:

- Control of the water diversion from Vu Gia to Thu Bon by building a regulatory installation at Quang Hue (a diversion in the lowlands), thus reducing the diversion of the calculated 40 m^3/s (see Figure 2.6, measure No. 2).
- Obstruction of salt water in the Vu Gia Delta (new permanent weir instead of temporary sand dams) (see Figure 2.6, measure No. 3).

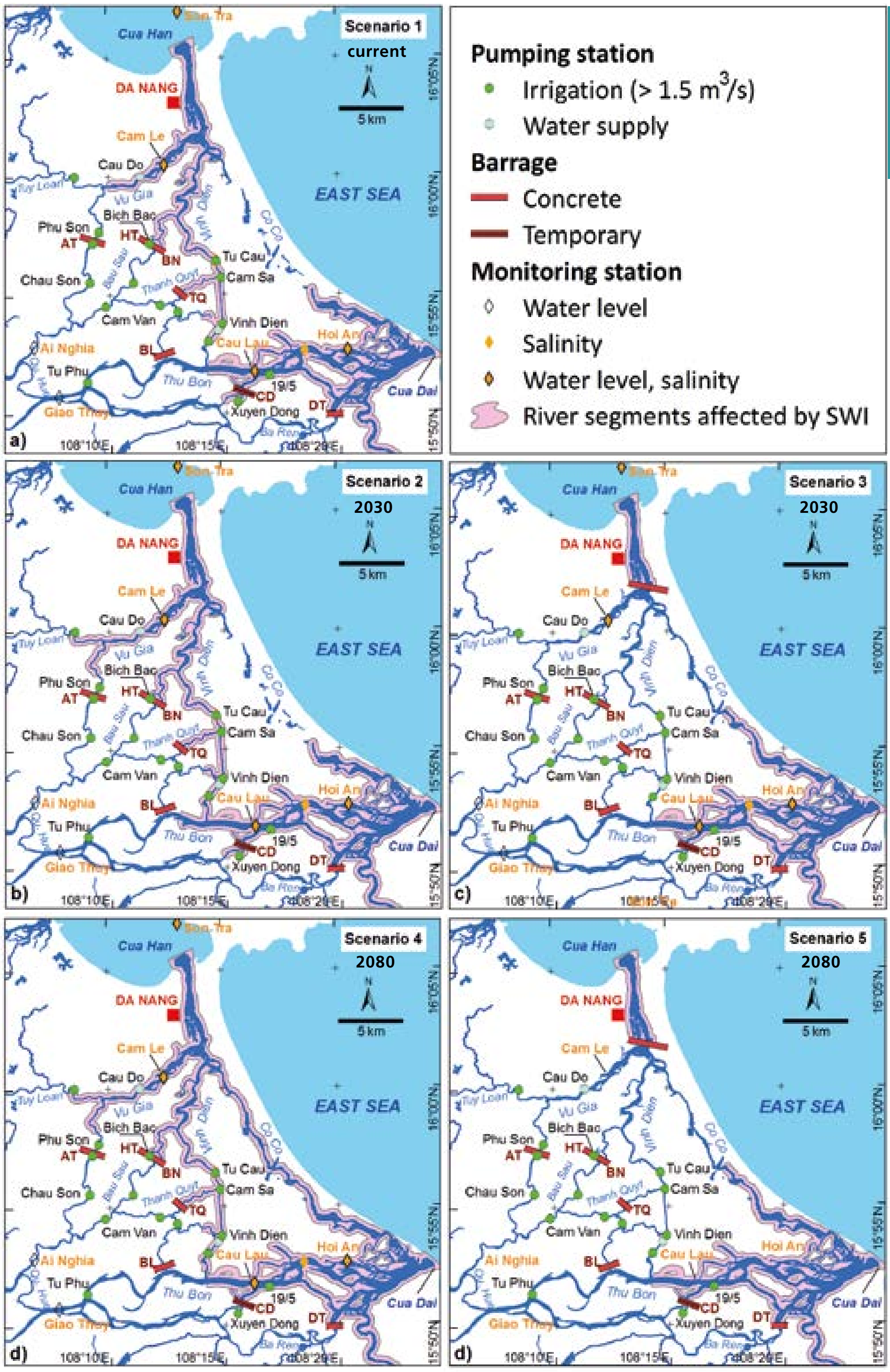


Figure 2.5: Saltwater intrusion hazard (SWI) for the current state (Scenario 1), mid-term 2030 (Scenario 2 and 3) and long-term 2080 (Scenario 4 and 5) in the delta of the Vu Gia and Thu Bon rivers, Vietnam , without/with adaptation measures. (Trinh Quoc Viet)

The modelled outputs of these scenarios were used to identify the pumping stations that were being subjected to saltwater intrusion. The hazard to a pumping station is also a threat to the irrigated areas that receive water from the stations. These hazards were mapped (Figure 2.5) and adaptation measures were suggested to address saltwater intrusion. For the current state scenario (S1), around 7,000 ha of agricultural land are under risk. Although saltwater intrusion increases without counter-measures under the model, in 2030 and 2080 less agricultural land would be affected because of the conversion into settlements – although the severity of the risk would be increasing. Scenarios S3 and S5 show the capability of adaptation measures to minimise the negative impacts of saltwater intrusion, as compared to S2 and S4 respectively.

Based on these scenarios a proposal for adaptation measures was suggested to address saltwater intrusion (Figure 2.6). These measures were formulated through field investigations, the consultation of local experts and numerical simulation:

1) Modification of the barrage operation
Redistributing upstream flow of estuarine tributaries by using the existing 4 barrage system. This is technically feasible without any further investment, but would require close cooperation between irrigation companies and water supply plants.
2) Controlling the water diversion from Vu Gia to Thu Bon via Quang Hue River
The Quang Hue diverts approximately 35 - 43% upstream flow of the Vu Gia to the Thu Bon. Vu Gia's diminished flow can cause severe saltwater intrusion downstream, where a large amount of freshwater is required for irrigation, salt control and urban uses. Regulating this diversion flow helps to increase Vu Gia's flow into the delta.

3) Construction of a saltwater obstruction
A new concrete dam as a saltwater obstruction is proposed downstream from the pumping stations on the Vu Gia river, instead of sand dams (see Figure 2.3 page 52). This will be built in 2017. It will control saltwater intrusion into the lower parts of the Vu Gia and keep it away from all pumping stations even under extreme low flow.

4) Improving irrigation efficiency by use of return flow from paddy farms
Substantial amounts of water applied to paddy farms are 'lost' in drainage, and it is valuable to store the drained water for re-irrigating in water shortage periods. This has been applied very successfully at Tu Cau irrigation scheme, which is severely affected by saltwater intrusion, and is being piloted in other schemes (see Figure 2.4 page 52).

5) Ensuring discharge from upstream by coordinating hydroelectric reservoirs
A multi-reservoir operation procedure is required to coordinate the discharge release of reservoirs. A minimum flow of approx. 150 m^3/s in total is needed to control saltwater intrusion without any other measures. During the dry season of 2014, under the coordination of Quangnam People's Committee, hydroelectricity reservoirs contributed positively to control saltwater intrusion (Figure 2.7).

In the dry season, available discharge regularly falls below the required 150m^3/s. Thus a combination of measure 5 with the other measures is needed to prevent saltwater intrusion. Saltwater intrusion in the Vu Gia Thu Bon and other coastal areas is becoming a severe problem, and is receiving increasing attention from local and national water stakeholders in the fields of hydropower generation, irrigation, resource management, environment and water supply. The need for cross-sector coordination and cooperation to develop joint management strategies for the river basin is becoming increasingly evident.

Beyond analysing problems and developing model-based recommendations, research institutions are able to take a neutral, objective, position within this 'stakeholder landscape' and can help balance the benefits and responsibilities between the different interests. A first step to create the necessary platform and support dialogue between the different groups of water and land users is the VGTB-River Basin Information Centre in Da Nang established by the research project (Figure 2.8; see Chapter 5 page 114).

Too much water/ flash floods
The Vu Gia Thu Bon lowlands in the rainy season is characterized by short and large-scale fluvial floods. Minor fluvial floods may occur more than once per season while extreme fluvial floods

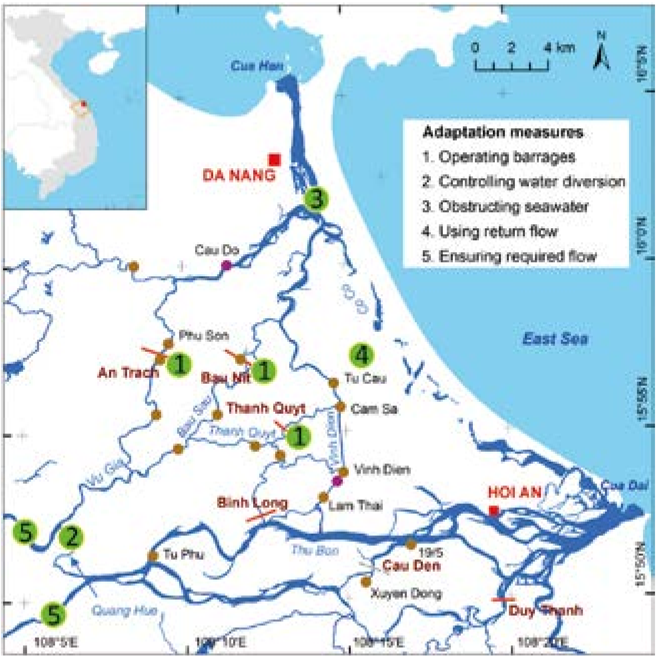


Figure 2.6: Recommended adaptation measures to address saltwater intrusion and their location in the lowlands of two river deltas, Vietnam. Brown circles indicate pumping stations for irrigation water and red lines indicate temporary dams to stop salt water intrusion. (Viet 2014)

occur every 20 - 30 years. The ongoing land use change, and climate change in the upstream mountainous area together with the ongoing reservoir management will intensify the flooding.

While damage to agriculture is low, floods in the VGTB lowlands are causing significant damage to settlement areas. Development plans foresee major changes focusing on an enlargement of urban and industrial areas. This intensive expansion is taking place within the floodplains.

Flood risk scenarios for 2030 have been developed to compare what is likely to happen if adaptation measures are implemented or not. The scenario for flood protection shows that the simulated hydraulic measures (additional discharge and river deepening) will not be sufficient to cope with flood risks. The simulation results led to the recommendation to focus on 'flood adapted land use'. This implies keeping the regularly flooded areas as free as possible from sensitive land use (mainly settlements and agriculture). Heavy tropical rainfall can fill reservoirs within one day, and afterwards lead to flooding if water from the rivers cannot be discharged fast enough.

Figure 2.7: An Trach barrage on the Vu Gia river, Vietnam. A similar weir could be constructed further downstream as permanent protection against salt water intrusion (measure No. 3). (Trinh Quoc Viet)

Figure 2.8: Stakeholder workshop in Vietnam: presentation of modeling results of different scenarios for coastal zone management and its effects on salt water intrusion. (Alexandra Nauditt)

Water management in the Okavango Basin and Delta

Upstream-downstream water relations within the Okavango Basin

context: the Okavango Delta with its rich biodiversity is dependent on the current water regime, where the uplands in Angola (forests and swamps) buffer the flow and extraction of water along the river. But irrigation is increasing, especially in Namibia affecting flow rates (and nutrient inputs) in the dry season, while the effects of CC are leading to higher and more frequent floods in the wet season and reduced flow in the dry season

problem: rice production developments may result in eutrophication of the water in the catchment. Currently, increasing yields and responding to growing food demands by rapidly growing populations is through expansion, but often on unsuitable land. Additionally, the growing demand for irrigation reduces flow into the lower parts of the river (delta) in the dry season

solutions:
- river basin management across sectors and borders (e.g. Okacom is a tripartite board with members from Angola, Namibia and Botswana that meets to discuss issues), integrated CC-Adaptation planning
- sustainable intensification and crops adapted to natural conditions, not only to conserve land but also water; instead of large-scale industrial agriculture with irrigation etc.
- balanced water needs for production and biodiversity in the upper regions of the basin

message: to protect biodiversity and secure environmentally important river flows while feeding a growing population across three national frontiers requires cooperation, coordination and consensus

The Okavango Basin includes areas of Angola, Namibia and the delta region in Botswana with its famously rich biodiversity. The survival of this internationally recognized biodiversity hot spot is dependent on sufficient discharge of the Okavango River and clean water, which is affected by many water and land uses throughout the catchment. Overall river basin management is essential, based on sustainable land management strategies balancing people's needs, seasonal water availability and nature conservation requirements. This integrated management approach is challenged by the fact that users from different countries and different land uses benefit unequally from the scarce resource: the water of the Okavango River (Figure 2.9).

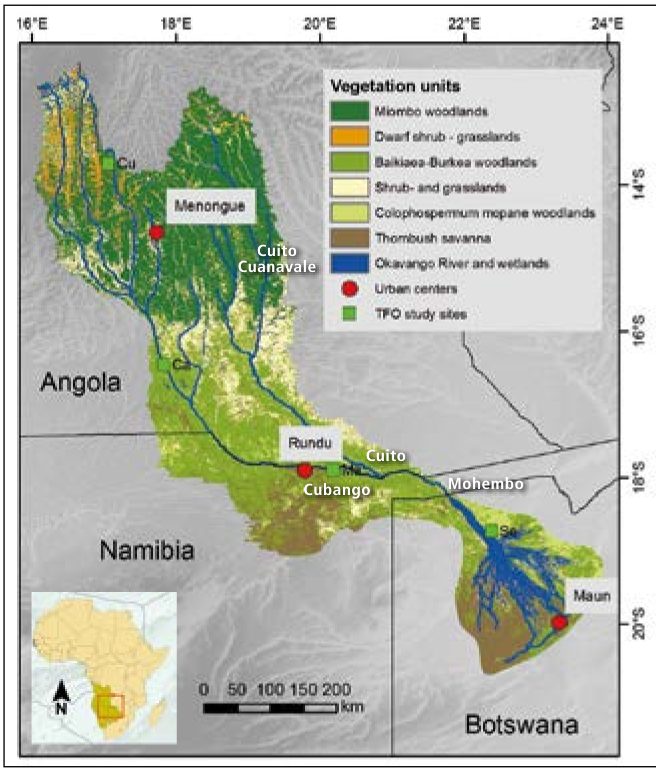


Figure 2.9: Overview of vegetative areas in the Okavango catchment with the location of the four core research sites: Cusseque (Cu); Caiundo (Ca); Mashare (Ma); Seronga (Se). The outline of the catchment in the climate scenarios below is slightly different and shows the whole hydrological catchment. (Jona Luther-Mosebach)

The water regime

Annual flow rates from the Angolan highlands to the Okavango Delta have been simulated with calibrated hydrological models. An upstream-downstream natural flow pattern, and the hydrological regime of the major tributaries from the Angolan highlands and the middle reaches at the Angolan-Namibian border, have been assessed.

The majority of the water flow is generated during the rainy season in the Angolan highlands in the catchments of the two main tributaries Cuito and Cubango (Figure 2.10). Here, peatlands within the

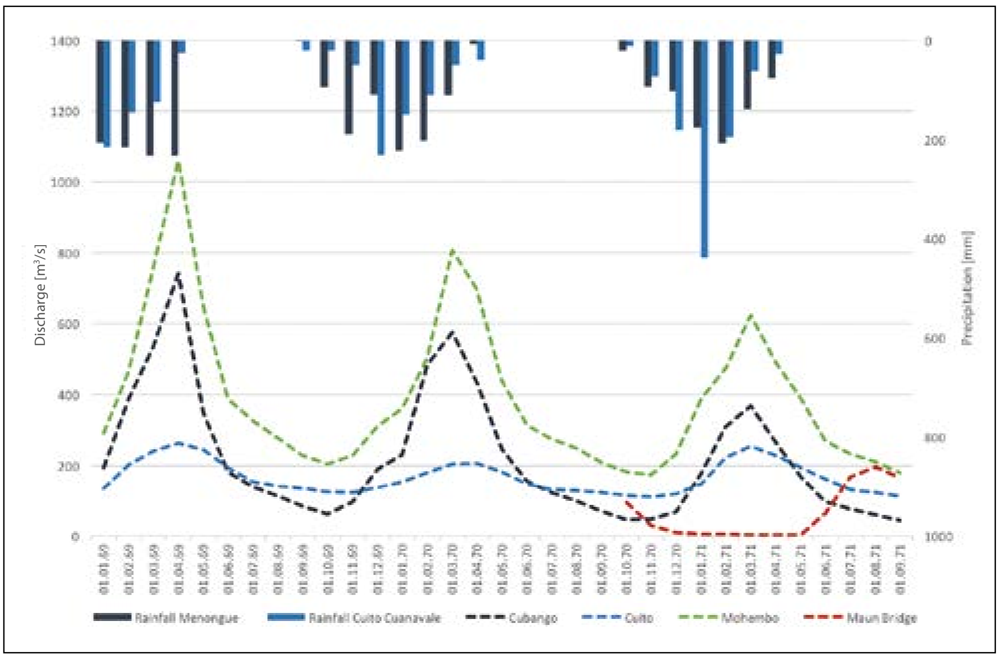


Figure 2.10: Discharge of the Okavango River at four water gauges from north to south: Cubango/ Cuito, Mohembo (Namibia) and Maun (Botswana) in relation to the precipitation measured at two stations in Angola (Menongue and Cuito Cuanavale). The discharge at the station in Maun is multiplied by 10 to illustrate the migration of the peak of the water flow towards the dry season. During the Angolan civil war from 1975 until 2002 , most data got lost and measurement equipment destroyed. Only old data from the archives were available. (Hendrik Göhmann)

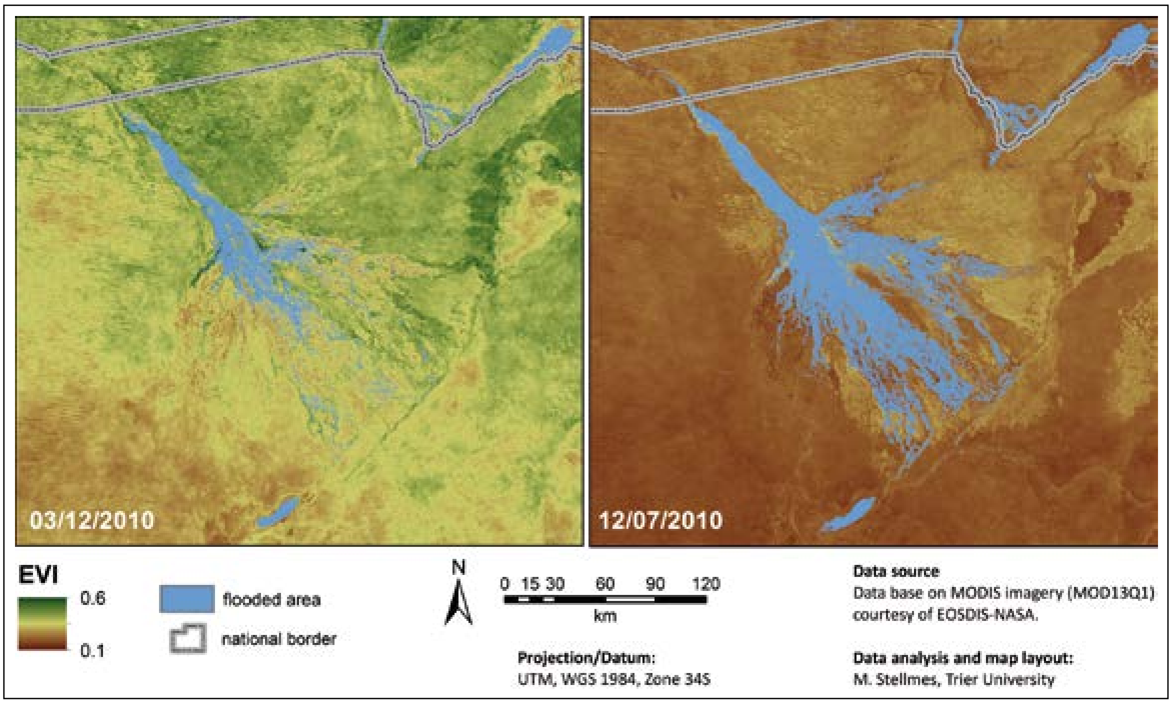


Figure 2.11: Map showing the Enhanced Vegetation Index (EVI) derived from MODIS Terra 16-day-composites for the Okavango Delta and surroundings. The EVI relates to green biomass cover and is illustrated as examples from the wet (03/12/2010) and the dry season (12/07/2010). Additionally, the flood extent of the delta is shown. The delta is fed by water from the Angolan highland areas. (Marion Stellmes)

valleys stabilize water quality and buffer peak flows. The river water entering the middle reaches in Namibia is of very good quality and only minor fluctuations can be detected during the year. Furthermore, the load of nutrients including nitrogen and phosphorus decreases towards the Okavango 'panhandle' which indicates that the river system is able to chemically buffer a certain amount of nutrients in the river discharge (Vushe 2014).

The Cuito, a main tributary with a strongly buffered flow regime, crosses the Kalahari basin without substantial conflux over a stretch of 280 km. Due to considerable meandering, the main stream has a length of about 450 km and a slope of only 0.2 m km^{-1}. About 650 km^2 of wetlands on sandy soils are associated with this river section, and these are able to store water in times of upstream peak flows – and to release water in times of low flows. The Cuito has a more even flow pattern, without the high peaks due to the rainy season in the summer (November-March). It is also the river that provides the delta with the necessary flood during the dry season (see red line in Figure 2.10). However, this discharge would be reduced if plans for large-scale irrigated rice production along the Cuito arm were implemented.

Water that is generated during the wet season in the highlands of Angola feeds into the delta during the dry season, making it a hugely important refuge for wildlife during harsh times, when water is limited in the surrounding area (Figure 2.11). The flood reaches its maximum extent during the dry season (June to August) and provides the delta's biodiversity with water at a time when it is otherwise scarce.

The current climate projections for the water flow regime, including all likely future changes, result in both higher and more frequent floods in the wet season, and reduced flows during the dry season. Here, the impacts of climate change up to 2030 will only have minor effects on the amount of river water reaching the delta. In contrast, land use/ cover change will influence the flow pattern more. The change in flow patterns will mean a dramatic impact on the lower reaches of the Okavango River (Proepper et al. 2015).

A changing climate increases fluctuations of water discharge

The future climate change scenarios for the catchment of the Okavango generally reveal decreasing availability of water due to an increase in temperature and a decline in precipitation. For the far future (2071-2100), the regional climate model REMO, enforced by two different general circulation models (GCMs): ECHAM and EC-EARTH, projects an increase in temperature of 2.0°C to 3.0°C under the low emission scenario (RCP4.5) (Figure 2.12 a/c) and of 5.0°C to 6.5 °C under the high emission scenario (RCP8.5) (Figure 2.12 b/d) for the basin. Furthermore, the projections indicate change in mean daily precipitation between -1.5 mm and +1.0 mm over the whole basin under the low emission scenario (Figure 2.13 a/c). Under the high emission scenario, the regional climate model projects a reduction of up to -2.0 mm for almost all areas of the basin, except for the uppermost north showing an increase up to 1.5 mm (Figure 2.13 b/d). The wetter highlands under both models will become wetter, while the drier lowlands will become drier. This is much more pronounced in the high emission scenarios compared with the low emission scenarios. The high emission scenario reflects 'business-as-usual'.

Projected climate change will affect the current rainfall pattern, by producing a shortened rainfall season (20 days reduction) and a partly reduced amount of precipitation in this part of the headwaters. Current average annual rainfall is 725 mm in the catchment. Furthermore, the middle and lower reaches may face considerable changes in their already low amounts of annual rainfall (-150 mm to -250 mm) and an increased temperature (+1.5°C to +2.5°C)]. Model simulations show that changing climate conditions up to 2030 will affect the amount of river water flowing towards the delta by less than 4% in general (positive and negative). Quantitative elaboration is difficult, as the comparison of simulated data for projections into the future and data analysis from historical measured values are not consistent. But the general trends suggest that water will be more scarce during the dry season, and this will affect all of the current land uses. Managing these fluctuations and scarcities requires a basin-wide CC adaptation strategy.

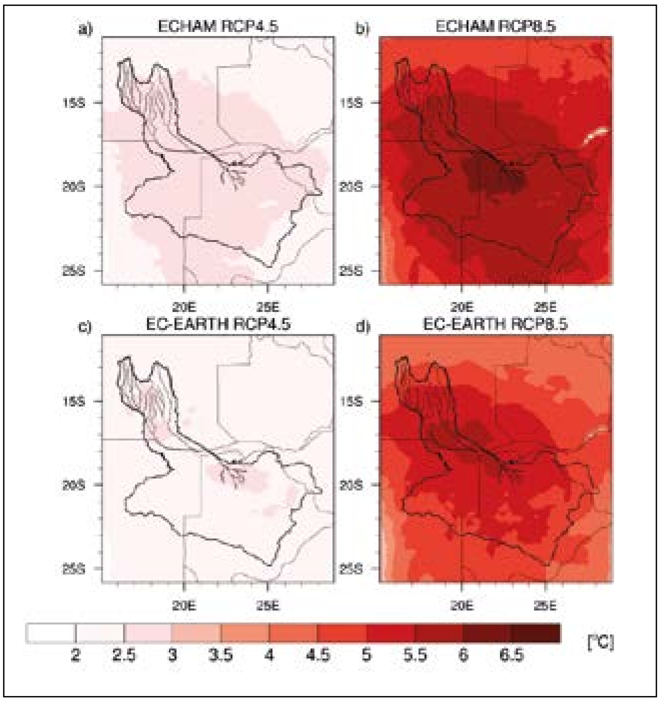


Figure 2.12: Projected changes by the regional climate model REMO for annual mean temperature [°C] for 2071-2100 compared to 1971-2000, Okavango Basin. The upper row shows the ECHAM and the bottom row the EC-EARTH forcing (GCM models). Left: low emission scenario (RCP4.5) and right: high emission scenario (RCP8.5). (Torsten. Weber)

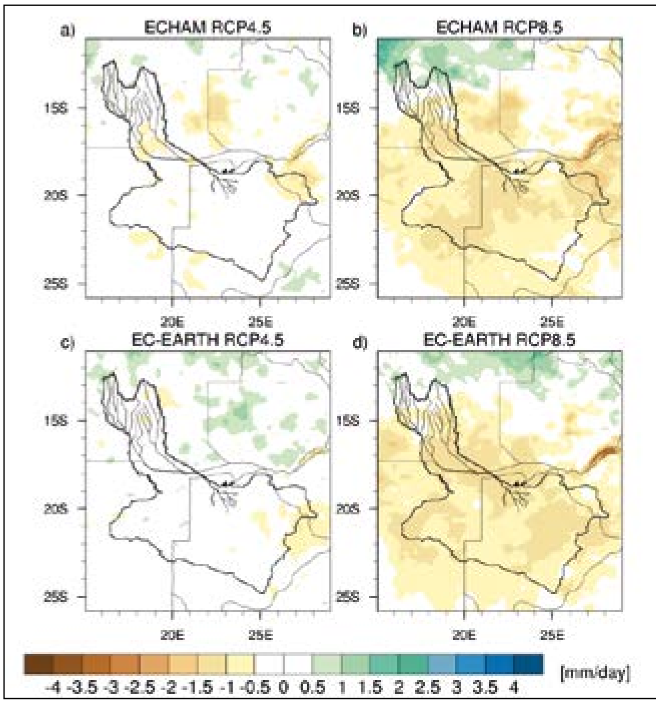


Figure 2.13: Projected changes by the regional climate model REMO for December-February mean daily precipitation [mm] for 2071-2100 compared to 1971-2000, Okavango Basin. The upper row shows the ECHAM and the bottom row the EC-EARTH forcing (GCM models). Left: low emission scenario (RCP4.5) and right: high emission scenario (RCP8.5). (Torsten. Weber)

Changing water demand by land use along the river

The water of the Okavango, throughout the entire catchment area, is utilized in various ways to meet social needs and to provide food stability and wellbeing. Major settlements along the river, as well as small villages along tributaries, extract drinking water from its reaches. Due to the sparsely populated catchment area, water abstraction for domestic supply has only a minor influence on flow rates and river discharge into the Okavango Delta (Figure 2.14). Until now, the production of agro-industrial goods along the rivers has been focused along the riverside in the Namibian part of the catchment. On these agro-industrial sites river water is utilized for large-scale irrigation techniques to grow cash crops such as maize in the wet, and wheat in the dry, seasons (Box 2.2).

Box 2.2: Water withdrawal for irrigation in Namibia

The current water extraction in Namibia is calculated to 4.3 m^3/s in total, future plans to expand irrigation agriculture on an area of 156 km^2 in Namibia are restricted to a total of 22.5 m^3/s river water extraction.

The current water withdrawal before the Cuito confluence reaches around 2.3 m^3/s and must not exceed 5.5 m^3/s, while downstream areas currently abstract around 2 m^3/s, but will reach 17 m^3/s through future planned schemes (Liebenberg 2009).

Figure 2.14: Okavango River and floodplains near Rundu, Namibia in the wet season. (Alexander Gröngröft)

Figure 2.15: Slash and burn farming in the woodlands of the upper catchment of the Okavango in Cusseque, Angola in 2016. (Stephanie Domptail)

In addition, within the headwaters in Angola, a number of large irrigations projects have recently been established, and others are in the planning stage. The rapid expansion of water extraction for irrigation in the headwaters is likely to affect dry season flow rates, and water quality by the accumulation of nitrate from fertilizers washed into the river.

Significant expansion of dryland fields in the area of the Miombo and Baikaia woodlands in Angola has already been observed. Around the centres of urbanisation and along the lines of settlements the proportion of smallholder fields has doubled in the last 20 years. This deforestation will affect the flow regimes in the headwaters of the catchment by increasing total flows in the wet season (see Chapter 3 page 82).

Runoff simulations that include deforestation effects lead to a stronger flood pulse during the rainy season, and stable or reduced low flow patterns. The peak flows appeared to be increased by 7% in general. The Okavango Delta in Botswana is dependent on inflow and evaporation. If inflow is reduced in the middle regions through increased irrigation and more conversion of forest to cropland in the upper regions, water supply and thus biodiversity is threatened by water scarcity and salinization. Climate change increases stress on both. A basic recommendation from current research is to improve monitoring and gain a better understanding of the water regime of the delta to be able to determine the minimum flow necessary to prevent degradation and loss of biodiversity in the delta. This knowledge is vital for sustainable management of the rest of the basin.

Optimized distribution of agricultural production

The biophysical conditions (climate, water availability and soil fertility) for crop production are crucial to the flow regime – but are relatively unequally distributed within the Okavango Basin. Whereas in the central and northern parts of the Okavango catchment, summer rainfalls tend to be sufficient for the production of maize, cassava and other crops, contrastingly, in the southern part, local farmers regularly experience years of low rainfall with low yields or crop failures, despite the focus on pearl millet as the main staple crop – an indigenous cereal that is well adapted to dry spells (Weber 2013). Yet expansion of land for crop production in the sparsely populated zones – and thus 'unused' areas of sub-Saharan Africa – is often seen as an option to cope with future food demands. This is an illusion.

The preferred landscape units for crop production are upper floodplains, dry river beds and fossil alluvial deposits, where soils are substantially more fertile than in the expansive areas of deep Kalahari sands. Estimation of the yield potential shows that, irrespective of landscape units, nitrogen in particular is deficient and in some places phosphorus also. Traditional crop production with low grain yields per hectare depends on the possibility of continuous expansion of fields into pristine areas in search of increased soil fertility (Figure 2.15).

Crop yields in the Okavango region vary with the climatic gradient from the head to the tail of the basin. Stable and comparably high yields in the semi-humid highlands of the upper catchment in central Angola are in strong contrast to the low and erratic yields of the semi-arid sections of the lower Okavango Basin. The latter phenomenon is partially caused by using rainfed farming practices that are better adapted to more favourable agro-climatic conditions and lower population density – as in the Angolan highlands – which are poorly suited to the soils and climate of the lower and drier basin. To a certain extent, these practices have been 'imported' through the migration of people and their customs to the semi-arid areas of the river basin. However, in the delta region of the catchment a farming practice known as *Molapo* farming is practiced in many villages adjacent to the delta. *Molapo* farming is 'flood retreat agriculture': namely the practice of planting crops on floodplains directly after the receding floods, which allows crops access to soil moisture in the absence of rainfall in the late dry season. Roots grow down and track the water table as the flood recedes.

Water available for plants production, through both irrigation and precipitation is becoming scarcer due to climate change (through projected temperature increase and reduction of precipitation; see Figures 2.12 and 2.13 page 57), and increasing water abstraction from the river by spread of large-scale irrigation. Low soil cover on fields with plants of pearl millet and maize further leads to high amounts of water loss by unproductive surface evaporation (Figures 2.16 and 2.17, Box 2.3).

Box 2.3: Riverine Forests and their role in evapotranspiration

As the Okavango Delta has no outlet, about 96% of the water inflow is lost via evapotranspiration (ET). Riparian woodlands occupy only 7% of the area but account for approximatly 27% of the total evapotranspiration. Thus any change of the riparian vegetation will have a significant impact – either if it decreases in extent, leading to higher water tables and flooding – or if it increases in area, water availability will correspondingly diminish with relative drying up of the delta. (Lubinda 2015)

In the future, the zone that is proposed for significant expansion of intensive agriculture is in the middle (mostly Namibia) and upper parts (mostly Angola) of the basin. These areas will be increasingly irrigated for crop production, leading in turn to more pressure on the river water resources during the dry season.

To fulfil the needs of a growing rural population and change in consumption patterns for higher yields, the research project has proposed sustainable intensification of smallholder production on the soils best suited to agricultural land use (see Technology 'Conservation Agriculture' page 247 and Chapter 1 page 30). In the southern, semi-arid, part of the catchment, crop production on deep sands depends on rainfall amounts and patterns in the growing season, which is associated with risks of crop failure. Here, woodlands are better adapted due to their deep rooting system, which is able to (i) take up water from deep layers in dry spells, and (ii) to prevent nutrients from leaching. These conditions lead to adequate growth of trees, and wildlife with high biodiversity and thus the potential to use these areas to provide ecosystem services rather than being cropped. This strategy would not only provide better food security but also decrease the pressure on water and thus reduce threats to the Okavango Delta.

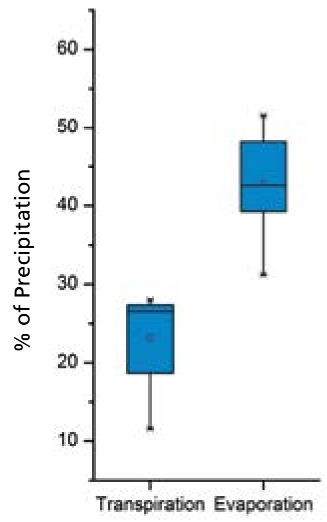


Figure 2.16: Relationship between actual transpiration and evaporation based on a thirty-year soil hydrological model run for dryland fields representing the core sites Cusseque, Mashare and Seronga (Lars Landschreiber unpublished data).

Managing water scarcity and quality in the São Francisco River Basin, Brazil

Managing too little – as well as too much - water

context: a massive expansion of irrigation area for energy (mainly sugar cane for biofuel) and food crops is expected; expansion into natural vegetation (*Caatinga* and riparian forests/ buffer zones); CC will increase weather extremes and evaporation

problem:
– water scarcity, even with the reservoirs
– low soil quality in some areas limiting growth
– soil erosion during heavy rainfall on uncovered soil with off-site damage (floods and decreased reservoir volumes)
– reduced water quality in reservoirs due to multiple causes (incl. agrochemicals, aqua-culture and urban waste water)

solutions: cross-sector management of a complex system, mix of technologies and governance
– use water more efficiently, e.g. micro-spray or drip irrigation, choice of less water-demanding crops and water pricing
– take all water users into account (required by law but not implemented), especially to avoid abrupt water level changes triggered by the electricity sector
– sediment retention dikes in dry river beds (multiple uses)
– conserve/ restore riparian forests as buffers
– incorporate fertilizer into the soil to reduce P losses by surface runoff, land-based aquaculture instead of net cages in lakes, measures at the source of pollution (e.g. mining industry), monitoring protocol

message: expansion of irrigation brings extra production but at the expense of water supplies: where water is short for other requirements a raft of different measures needs to be planned and implemented to offset the shortfall

The population within the São Francisco River Basin, Brazil, is increasing, and food and energy demand along with it. As a consequence, a massive expansion of the irrigation area for energy (mainly sugar cane for biofuel) and food crops is expected. In general, irrigation area expansion is considered a major rural development measure in Brazil. However, water for irrigation will be even scarcer than it is already today – and regional differences in soil types will be a limiting factor on agricultural production. The more fertile soils in the middle portion of the river basin are

Figure 2.17: Uncovered soil gives rise to high rates of unproductive surface evaporation, Okavango Basin. (Alexander Gröngröft)

predetermined for expansion, whereas the highly populated semi-arid lower-middle region need income generation options for people, calling for an increase in irrigation. According to modelling results (see Chapter 1 page 42), cropland will further expand at the expense of natural vegetation (*Caatinga* in the semi-arid portion of the river basin) and pasture; land allocated for maize production will decrease, while it will increase for sugar cane. This will elevate the water demand for irrigation in a semi-arid area. At least part of the agricultural area expansion will be at the expense of areas with natural vegetation, ever more threatening the *Caatinga* woodlands with their unique and climate-adapted biodiversity. Figure 2.18 is an overview of the São Francisco River Basin. This land conversion would increase the potential for soil erosion when soils are, at least temporarily, uncovered, and threaten the quality and quantity of water resources when vegetative buffer zones along water bodies or around sources are removed.

Figure 2.18: Overview of the São Francisco River Basin (Siegmund-Schultze et al. 2015b).

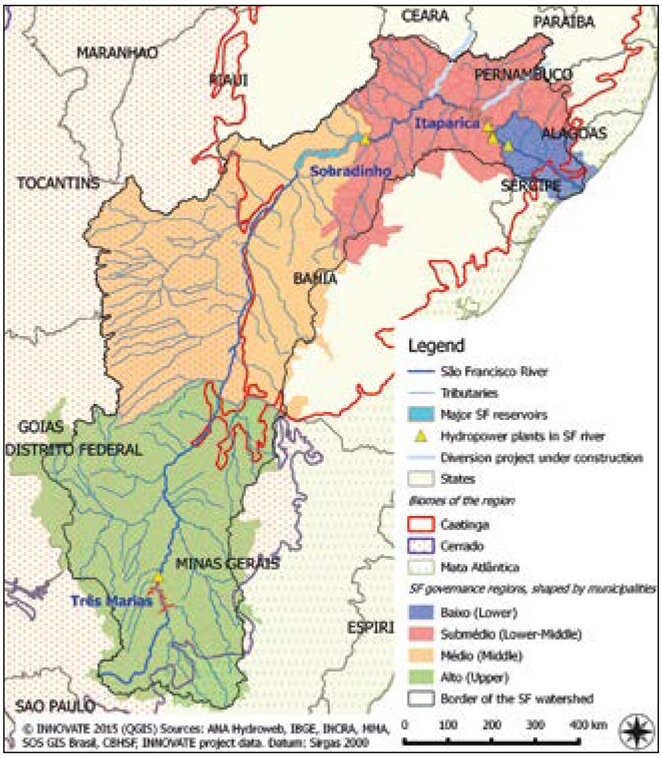


Figure 2.19: Dike (check dam) near to a Pankarará indigenous village shortly after construction (left), two years later with grass and trees (right), São Francisco River Basin, Brazil. (Pierson Barretto)

As the water demand of different users increases in the future and water becomes scarcer, the challenge is how to assure that there is no waste and overuse of water, and how to allocate the scarce water amongst potentially conflicting uses within the river basin. Besides satisfied water demand in the future (Table 2.2), the occurrence of consecutive dry years is likely to increase – and this even in the wetter climate scenarios. Hence, planning for prolonged drought periods will be required in any situation.

Table 2.2: Projections of future water demand covered in the São Francisco River Basin, according to different climate scenarios and two study periods (mean of study periods). Percentage covered: available/ demand × 100. (Hagen Koch)

	Wet climate scenarios		Dry climate scenarios	
Period	Available (m^3/s)	Percentage of demand covered	Available (m^3/s)	Percentage of demand covered
2021-2050	412	87 %	325	48 %
2070-2099	420	88 %	139	29 %

Results in relation to improved river basin management indicate that all relevant plans (particularly those f hydropower and irrigation) must be coordinated and take into account that there will be less water available in the future. Some of the plans for additional irrigation schemes are unrealistic under the projected climate conditions. It is also the case that, for the local population, these plans are often not transparent. There is an existing river basin committee, however the role of the different sectors, agencies and ministries involved is not always clear. The problem heightens with the increasing water scarcity caused by growing demand and climate change factors, and can only be partly mitigated by many additional dams. Under the current and predicted droughts there will not be sufficient water to satisfy all the claims made on it.

The São Francisco River Basin is highly regulated by man. Water quantity is a question of legal and illegal withdrawals and reservoir management. Low water level periods resulting from poor rainfall can easily be turned into high water level periods – but only as long as reservoirs are full. To complicate matters further, periods of high rainfall could be accompanied by low water levels, while water is being stored in the reservoirs. While regulation of the water flow has buffered and secured the water flow during a series of drought years, if climate change and increasing demands are combined, future low flow might not be secured. So far, decisions on water release are primarily based on national energy needs rather than negotiation among all water user groups. A participatory management practice, based on the above mentioned river basin committee, accounting for all different water uses is required by law. The adaptation of the established institutions to the new participatory process has not yet taken place (Siegmund-Schultze et al. 2015a). More efforts by all people and institutions involved are needed to champion further collaboration and fair allocation of water.

Managing too much water

Even though climate scenarios project different trends in terms of mean annual rainfall, a general finding is that temperature and weather extremes will increase, meaning that severe droughts will last longer in the future and heavier rainstorms are expected both in humid and semi-arid environments. Depending on the land management, this would result in high runoff and consequent soil erosion during heavy rainfalls. This impacts downstream areas with flooding along the river and the reservoirs, as well as increased sedimentation – initially in the first reservoir in the sequence of the three major ones.

Before the completion of the reservoirs, river flow fluctuations were much more pronounced than afterwards. Beside their use for hydropower, the reservoirs were built to reduce flood risks. Yet, given more extreme future weather events, the capability of the reservoirs to prevent future risk of flooding is not clear. Today there are regulations for maximum flow of the rivers. As long as the reservoirs can store water and the flow is regulated accordingly, the settlements will not be inundated. This regulatory capacity of the reservoirs could be surpassed if, instead of the more probable consecutive dry years, the opposite was to occur: consecutive wet years. There are regions where all climate models give the same trends. North-east Brazil seems to be a region, where many models still have problems with precipitation. Hence, some climate models do not yet have the accuracy to provide projections at the required regional scale to assess those extreme events.

To prevent erosion in cases of heavy rainfall in otherwise dry areas, installing artificial barriers – namely stone check dams, or dikes - in dry river beds has been tested in a few communities of the São Francisco River Basin. These dikes (a well-known traditional system used in many parts of the world) as in the example of the '*Conceito Base Zero*' turn erosion by water into a benefit, through accumulating sediments deposited by storm water. These nutrient-rich sediments provide extra soil with better water-holding capacity for crop growth.

Although the region of Itacuruba has a relatively flat topography, soils are very sensitive to erosion. The climate is semi-arid; rainfall averages are about 400 mm annually, though in drought years rainfall may not even reach 100 mm. Furthermore large parts of the annual rainfall can sometimes occur in periods of a few hours, causing flash floods. Streams in the semi-arid region are intermittent, only carrying water immediately after rainfall events.

Figure 2.20: Construction of a dike in the Quilombola community Poço do Cavalo (left); Transport of stones for the construction of a dike (right) São Francisco River Basin, Brazil. (Pierson Barretto)

Check dams (dikes) are water and sediment harvesting systems. Dikes reduce flood speed and erosion, increasing water infiltration, and reduce the amount of sediments ending up in lakes and reservoirs. This contributes to improving water quality, while also increasing the availability of water for the environment and for economic uses. The improved soil water conditions nearby the dikes allow grass and trees to grow, which can be grazed and browsed by livestock and can sustain bee-keeping (Figure 2.19).

During the dry period, people determine the location of crescent-shaped stone walls (termed 'eye-brow' terraces or 'half-moons' elsewhere in the world) to be placed across the stream flow. The stones are stacked without using cement (Figure 2.20). This can be organized as a community activity, to be implemented within one day. A sediment marker is placed to monitor the development of sediment retention. The activity is based on labour input only. The existence of nearby stones is a prerequisite.

To reduce flood risks and sedimentation flow to the reservoirs, vegetated buffer areas (as stipulated by law) would need to be conserved and/or restored and settlements must not be established too close to the shore. Restoration of vegetation and riparian forests around sources, and along river banks, for improving infiltration and groundwater recharge is an on-going activity, promoted by the river basin committee and nowadays implemented with the support of governmental programmes as well (see Section 2.2 page 63).

Managing water scarcity/ too little water

As weather extremes are expected to increase, periods of prolonged drought will also become more common not only in dry, but also wetter (semi-humid to humid) environments. Therefore, the pressure on available water resources is increasing (Figure 2.21). At the same time, the demand for water and its abstraction is increasing. In the upstream areas, i.e. the generally wetter part of the basin, droughts are expected to lead to reduced water flows and low levels in the reservoir. In the middle and downstream areas, expansion of large irrigation schemes will increase demand for, and use of, water. Furthermore, the large reservoirs in this section of the river basin and the open irrigation channels are subject to enormous losses of water due to evaporation (Figure 2.22).

A challenge connected to water quantity is the management of flow (via reservoir management) leading to abrupt water level fluctuations in the reservoir, which are very different from naturally occurring seasonal changes over the year. Abrupt changes negatively affect reservoir ecology (drying out of macrophytes, which release high amounts of nutrients into the water) and negatively affect users who have to respond to water level changes (for instance, a boat moored in the morning may be beached at the end of the day). During droughts, low river water levels will increase the sedimentation already within the river, impeding or at least further complicating the river's use for transport.

A first step to improving water allocation is investment in irrigation infrastructure with reduced water loss and better water use efficiency. A change of infrastructure to the more efficient drip irrigation (see Chapter 1 page 33) would be effective in reducing water demand. Another step for regions with uncertain water availability is to avoid cultivation of water-demanding crops such as sugar cane, and instead favour plants which are less water-demanding such as coconut and food crops. Simultaneously, planners of new irrigation schemes should harmonize development plans with water permit organizations (at federal or state level, depending on the type of the river) and organizations responsible for water management (river basin committees) in order to estimate future water availability, and follow decisions on prioritization of water allocation.

Figure 2.21: Empty water body after a dry period, Brazil. (Maike Guschal)

Figure 2.22: View over outskirts of Petrolândia town with some irrigation along the reservoir's shoreline – the huge surface area of the Itaparica reservoir, Brazil supports substantial evaporation losses. (Verena Rodorff)

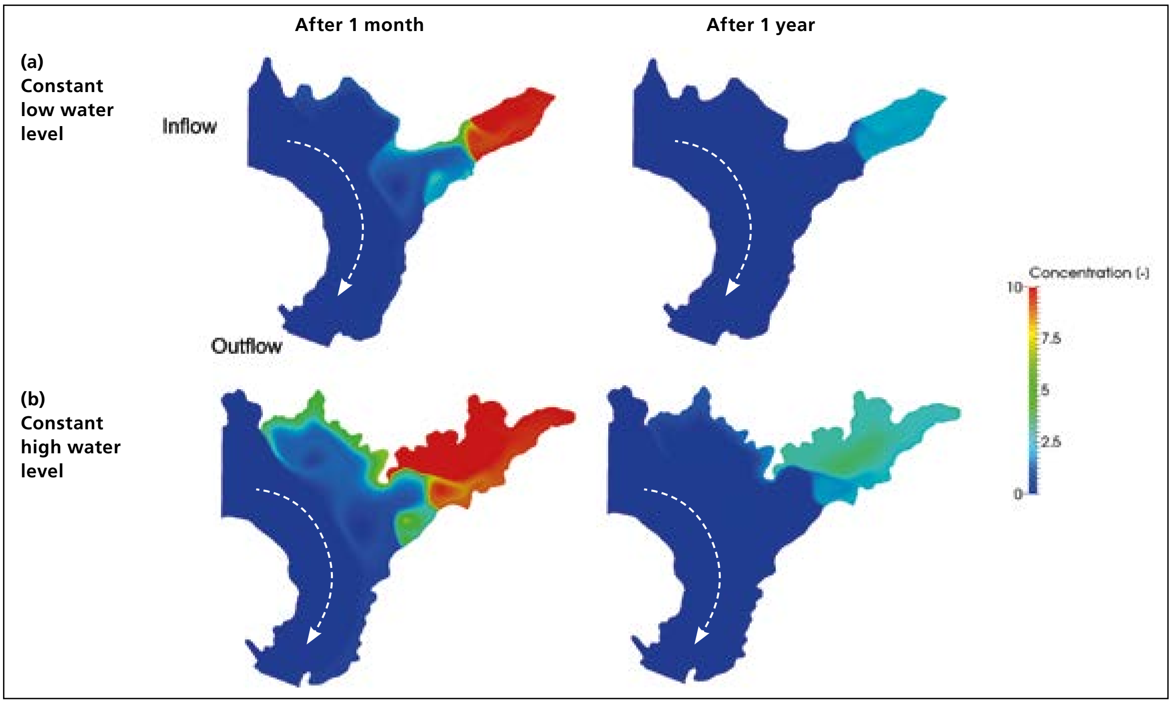


Figure 2.23: Water residence time in a bay of the Itaparica reservoir, Brazil under low (a) and high (b) water level conditions. Note: The arrow indicates the reservoir's main stream flow. (Elena Matta)

Modelling future water quantities and river flow under different land use patterns (SWIM model, MAgPIE model) and different climate change scenarios, allows the estimation of how much water will be available for irrigation in the future. A model-based upstream-downstream water management plan has been suggested for improved allocation of water, including the ecosystem as a 'water user without a voice'. The simulated options include a reduction of water level fluctuations in the reservoir to (i) 0.5 m per year, (ii) a maximum of 5 cm per day, and (iii) accounting for a minimal ecological flow (Koch et al. 2015). All options have an impact on hydropower generation. Limiting daily fluctuations to a 5 cm maximum turned out to be the most flexible, the easiest and most realistic management option to implement. The remaining flow capacity can then be allocated for generation of hydropower and for consumptive use. The recognition of consequences, and probable quantitative outcomes of management decisions, is not easy due to the inherent complexity. Finally, hydrological, and hydro-economic modelling as well, are means to quantify and compare outcomes. The modelling shows the consequences of reservoir release rules for water users, and serves as a foundation to discuss regulations with members of the river basin committee, and a base for the negotiations between the different users and uses.

Impacts of human activities and storm water events on water quality

Sediments and nutrients entering surface waters from diffuse sources (e.g. erosion, interflow, or groundwater) and from point sources (e.g. wastewater treatment plants or sewer systems) impact on, and cause a decline in water quality. Reduced river flow or direct addition of nutrients from aquaculture can exacerbate water pollution (for example eutrophication), in particular in reservoirs and lakes. Nutrient (N and P) emissions to surface water, instream transport and retention as well as the resulting water quality was modelled using MONERIS. The major source of nutrient emissions was urban areas, where households were connected to a sewer but not to a treatment plant: this turned out to be the major polluter. The few wastewater treatment plants that exist are often designed to reduce the biological oxygen demand but barely retain nutrients from the effluents. Since the major population lives in the upstream area of the watershed, the greatest share of emissions originates from this part. Furthermore, favourable climatic conditions in the upstream catchment lead to intensified agriculture, which causes additional nutrient emissions. In spite of high nitrogen losses due to denitrification during transport in the river system, emissions from the upstream catchment provide the major share of nitrogen in the lower sections of the São Francisco also. In the case of the Itaparica reservoir, located in the sub-middle region of the watershed, 90% of the entire nitrogen load enters the reservoir with the discharge of the main river São Francisco, exceeding by far emissions from the adjacent catchment of the reservoir. In the direct, sparsely populated and less intensively used catchment of the reservoir emissions are mainly caused by erosion, interflow and from urban areas, entering the reservoir, in particular, during storm water events in the short rainy season. Diffuse nutrient emissions from agriculture are an emerging threat, and are likely to increase in future with the expansion of irrigated and intensified agriculture.

Currently, however, nutrient concentrations are low in most river sections as well as in the reservoirs and eutrophication is, so far, only a temporary threat. The latter is, in particular, the case for bays of the reservoirs, mostly isolated from the main reservoir body, where longer residence time and less water exchange favour algal growth and eutrophication. Tracer transport simulations (Figure 2.23) show that the bay's water flow behaves differently from the reservoir's main flow. Pollution resides for a longer period of

Figure 2.24: Green Liver System for treating aquaculture effluent, Brazil. (Johann Köppel)

Figure 2.25: Deforestation along the BR-163 highway: Pará in the pioneer zone (left) and Mato Grosso, Brazil with large-scale soy plantations (right). (Stefan Hohnwald)

time in a bay and the phenomenon cannot be improved by flooding the reservoir since residence time in the bays is even longer under high water levels. It is recommended that water monitoring and abstraction of drinking and irrigation water take these spatial differences into account. Water users should be aware that water pollution in the bays can be increased and remain high for a longer period without being diluted than in the reservoir's main stream.

Emissions from agricultural areas are expected to increase because of planned expansion of agricultural land in the catchment. An analyses of regional agricultural cultivation practices resulted in two major findings: First, the degree of phosphorus saturation (DPS) of soils is generally low, indicating low risk of P losses in the studied region. Second, the common practice of top-dressing/ broadcasting with fertilizer (Portuguese: adubação de cobertura) results in high risks of P losses from farm land. Incorporation of fertilizer into the soil should reduce the risk of P losses, and also potentially be beneficial for plant growth.

This combination of different measures addressing specific sources of water pollution within the river basin can improve the overall water quality of the São Francisco (Figure 2.23). This also includes a new technology to naturally clean water from fish ponds before discharging it into the reservoir (Figure 2.24; see Technology 'Green Liver' page 167 and Chapter 1 page 38)

Within a simulation model, a tracer was applied uniformly, with an initial concentration of 10, in an outer bay area with a consistently low water level (a). After one month, ca. 65% of the tracer was still retained in the bay, while after one year 15% remained. In the same simulation, but in a bay with a high water level (b), after one month, ca. 80% of tracer was still retained in the bay, but in this case after one year the amount retained was more than 20% (Matta et al. submitted).

2.2 Riparian forest and water quality management

Riparian/ gallery forests are a specific type of buffer zone in the river basin providing a set of ecosystem services that affect many other land and water uses. Riparian forests – that is strips of trees along rivers – have positive effects including:
- providing a buffer and filter, and improving water quality of rivers in areas of intensive agricultural production system;
- preventing soil erosion alongside rivers, and bank erosion, as well as filtering sediments out of runoff water from farmland before discharge into rivers and reservoirs;
- providing a zone which enhances groundwater recharge; and
- slowing down and reducing peaks of high flows and floods (and accumulating sediments) thus reducing flood risks and associated damage.

Three examples of land and water management in riparian forest are presented below:
- Spring and gallery forests protecting water in Mato Grosso region of the Amazon in Brazil
- Riparian forests and salinity management in the Tarim Basin, China
- Water protection zones for springs and rivers in rubber plantations, China

Spring and gallery forest protecting water in Mato Grosso region of the Amazon in Brazil

Spring and gallery forests as an effective buffer to hold precious soil and fertility

context: a high yield production systems with fluctuating rainfall patterns - efficient use of scarce water for today and in the future; if gallery forests are cut, springs and small rivers dry up

problem: deforestation due to expansion leads to higher runoff, erosion and less infiltration, higher peaks/ lower dry season flows during the year

solutions: protect spring and gallery forests as buffer zones to protect water quality and prevent erosion. If converted to cropland use contour banks and no-till farming

message: naturally occurring forests around springs and rivers (gallery or riparian forests) are very important for multiple reasons and are priorities for protection

In the Mato Grosso region of the Amazon in Brazil challenges of water management are focussed on efficient use of scarce water for today – and the future. Due to the pronounced seasonality of precipitation, water management and land use have to cope with the dual risks of water erosion due to heavy rainfall during one period, and water scarcity at other times. The region is also affected by ongoing land use change as forest is converted to pasture – and then after several years of use to cropland (Figure 2.25).

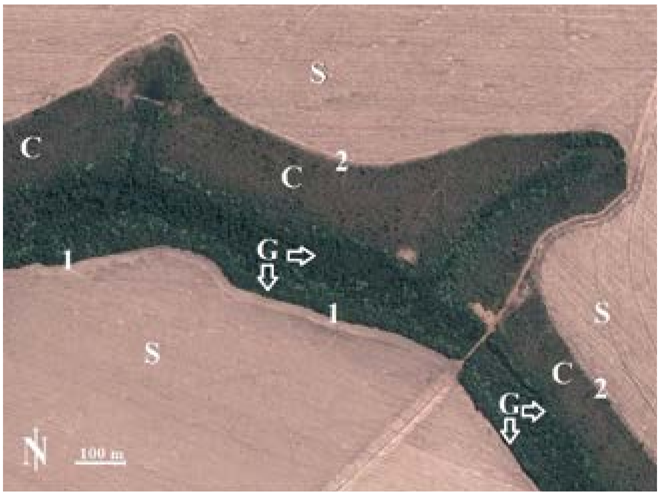


Figure 2.26: *Cerrado* dry forests (C) and gallery forests (G) along a river bed within intense soy production cropland (S); 1: evergreen gallery forests and 2: *Cerrado* forest patches. (Stefan Hohnwald)

The deforestation front is moving from the drier areas, formerly covered with Cerrado dry forest, into the wetter areas of the Amazon rainforests. Between the high intensity agricultural production areas that were converted in the 1960s, and the still intact forests, land use is a mixture of cropland, pastures and gallery forests left along rivers (Figure 2.26).

To study water quantity and quality under different land use systems, micro-watersheds with different land uses within two meso-catchments in the Amazon area (still intact forest and pasture) and in the *Cerrado*/ savannah area (cropland, pasture and remaining *Cerrado* forest) were compared (Figure 2.27). The data showed that pastures in both areas have higher runoff with the associated danger of soil erosion, especially after heavy rain events and peak flows. Spring and gallery forests can act as effective buffers to hold precious soil and retain fertility. Water quality in the streams has not yet been negatively affected by agriculture, and is well protected by gallery forests – to the extent that crystal clear water was running in the smaller streams. This shows that agricultural soils, after management of 30 years and a buffer with natural vegetation, still possess the ability to store and buffer nutrients and maintain their fertility.

The removal of forest cover associated with agricultural expansion changes the water balance within a watershed. In this context, river headwater catchments play an important role in understanding the influence of human and climate changes on streamflow dynamics. Their relatively small contributing areas make them highly responsive to changes in water flows.

To verify the hypothesis that clearing of native vegetation for agricultural development in the Amazonian agricultural frontier leads to an increase of river discharge with higher flood risks, two pairs of headwater catchments were examined. In both, the Cerrado and the Amazon ecotones, the measured river discharge is higher for the pasture land-use type (Figures 2.28 and 2.29) for most of the study period. This is attributed to the compaction of upper soil layer by cattle grazing and machinery use in the pasture areas, leading to reduced water infiltration rates and higher overland flow. In phases of conversion of forest to pasture, and of pasture to the mono-cropped agro-landscapes, surface runoff and soil erosion peak because of uncovered soil. They decrease again after the new land use is established. In the established cropping systems, the erosion problem has been addressed through the adoption of practices of contour earth bunds and no-till agriculture (see Chapter 1 page 25). Thus runoff and erosion are lower than in pasture systems: a surprising finding.

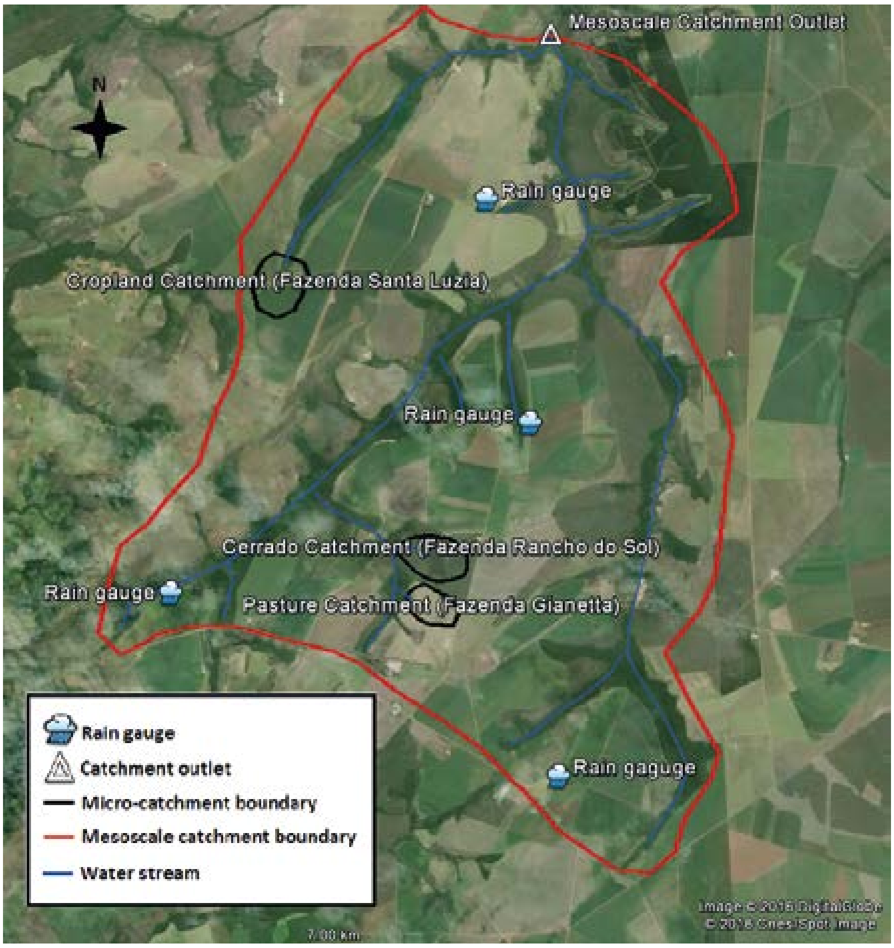


Figure 2.27: Tested micro-catchments (black circles) in a larger meso-catchment (red line) in Central Mato Grosso (Rio Das Mortes) with mixed land use: cropland catchment (Santa Luzia), *Cerrado* with mixed forest and shrub catchment (Fazenda Rancho de Sol), and pasture catchment (Fazenda Gianetta). (Carbiocial)

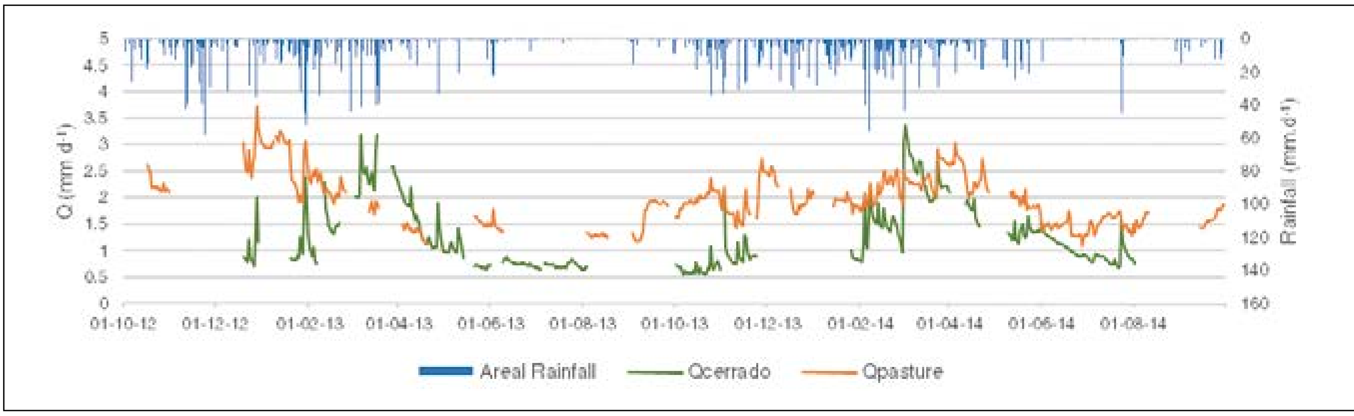


Figure 2.28: Discharge (Q) and rainfall records for a savannah forest catchment (Qcerrado) and a pasture (Qpasture) in the dry forest of the *Cerrado*, Brazil. (Carbiocial)

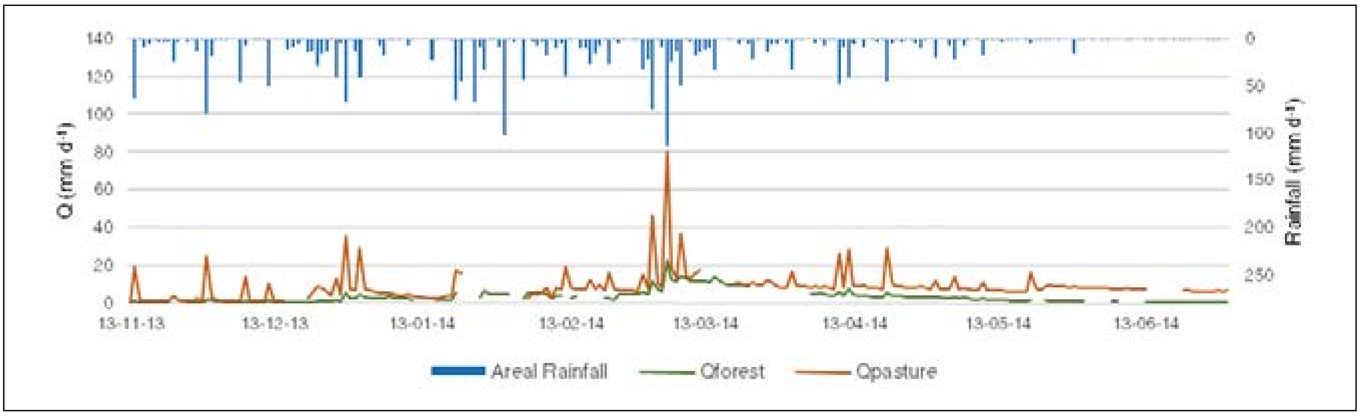


Figure 2.29: Discharge (Q) and rainfall records for a rainforest catchment (Qforest) and a pasture (Qpasture) in the rainforest of the Amazon, Brazil. (Carbiocial)

In this context, the hydrological soil water assessment tool (SWAT) and erosion simulation models (EROSION-3D) were used to assess the impacts of deforestation and conversion to agro-pastoral landscapes under different land management in the *Cerrado* (savannah) and Amazon (rainforest) vegetation.

Figure 2.30 shows the increase of runoff and erosion risk in relation to land use. Runoff increase is highest for pasture, and the erosion risk is highest for the fresh deforested *Cerrado*, followed by cropland under conventional tillage. The results also show that contour earth banks/ bunds significantly decrease runoff and erosion risks for both pasture and cropland. The lowest risks are associated with the combination of both land management methods for cropland.

Because spring and gallery forests act as buffer zones, improving water quality, one important governmental edict to protect water quality is the obligatory protection of gallery forests in Brazil. The law protects 50-80 m wide buffer zones, measured from river banks, and is controlled by the (strict) Brazilian Institute of Environment and Renewable Natural Resources (IBAMA, the administrative arm of the Brazilian Ministry for Environment) through satellite images, and exacting financial punishments for non-compliance. The ecological effects of these buffer zones is also being investigated in relation to C-sequestration (soil buffers). The project provides answers to the ecological and economic benefits of the protection of gallery forests and springs for the micro-catchment, as well as the whole river basin (macro-catchment).

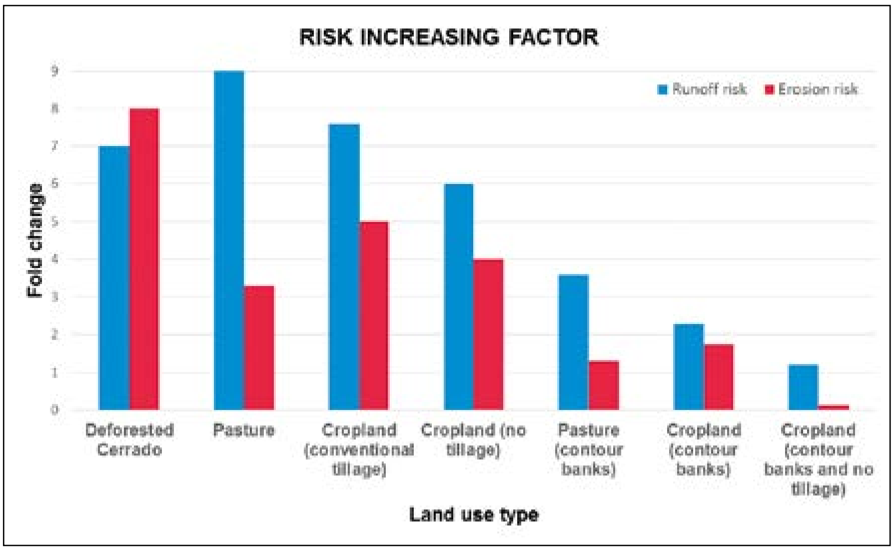


Figure 2.30: Risk increasing factor (fold change) due to different agricultural land use practices after conversion of *Cerrado*. Forest equals 0. (Marcus Schindewolf and Jürgen Schmidt)

In cases where the gallery forests are intact, the water quality of the springs is very high, even in areas of large-scale industrial production systems with use of agro-chemicals.

Also, if spring and gallery forests are cut, springs dry up and after heavy rainfall events soil, nutrients, and agrochemicals are eroded and washed down into the lower parts of the catchment. The forests filter the runoff water and soil is deposited in them. In addition, gallery or riparian forests provide habitats for biodiversity.

Water salinity management in the Tarim Basin and the potential role of the riparian forests, China

High water consumption for cotton in desert conditions, water stress and a potential contribution from riparian forests

context: due to the low precipitation and high evaporation rates, the region's water supply depends solely on the river

problem: upper basin increase of irrigation and water use, middle and lower basin too little water from the river; glacier/ river water only secured until 2050, then decline. Use of groundwater for irrigation, not enough groundwater recharge through flooding

solutions: river basin water management
- preserve/ re-establish riparian forests for ESS (windbreaks, groundwater recharge, reduced erosion, biodiversity etc.)
- allow natural summer floods esp. in the middle basin for riparian forests and groundwater recharge
- mix of irrigation with groundwater and river water based on season combined with more efficient use of water resources
- mosaic of fields and natural vegetation

message: Riparian forest have a potential role in addressing water shortages downstream. They bring other benefits too, and should be protected and nurtured as a valuable contributor to the environment – and agriculture

The Tarim River in north-west China runs along the northern rim of the Taklamakan desert. Its water originates in the glaciers of the Tian Shan Mountains. Due to low precipitation and high evaporation rates, the region's water supply depends solely on river water. The Tarim River has its highest flow during summer due to glacier melt. Farmers are tending to expand agricultural fields in the upper reaches, consuming more water and leaving less for the middle and lower reaches of the Tarim River. Due to poor water allocation arrangements, too little water is available in the lower reaches, leading to the drying-up of this region.

Climate change models project that, due to global warming, additional glacial water will be available in the river for the forthcoming decades until 2050. However, afterwards, river flow in the summer period will decline. As glaciers are going to provide less water, supplies for irrigation will be become increasingly limited during the summer period, and sustainable water management options will be needed to mitigate the problem. The pressure on groundwater use – even though prohibited by law- is likely to increase. In addition, since crop production is prioritized, the natural vegetation and riparian forests are suffering additional water stress, and the ecosystem services provided by them are decreasing: providing habitats for unique plants and animals, diminishing effects of sand storms and soil erosion, providing wood supply – and, especially, groundwater recharge.

For improving groundwater recharge in the Tarim Basin, three key steps need to be undertaken (i) provide a greater area for natural flow along the river banks (i.e. do not allow encroachment), as the original slow flowing and meandering river favoured high groundwater recharge within the adjacent riparian area; (ii) allow 'ecological flooding' of natural riparian areas in the upper and middle reaches of the river, as in the summer the river has its highest peaks and floods due to snow and glacier melt. This will contribute to groundwater recharge and therefore to the preservation of natural vegetation; and (iii) enhance the infiltration rate in these groundwater recharge zones by establishing additional areas with riparian forests.

The importance of groundwater recharge within and along the river during the year and especially in the summer flood peaks is summarised in Figure 2.31, showing the annual groundwater recharge and discharge in the middle reaches of the Tarim River for 2012.

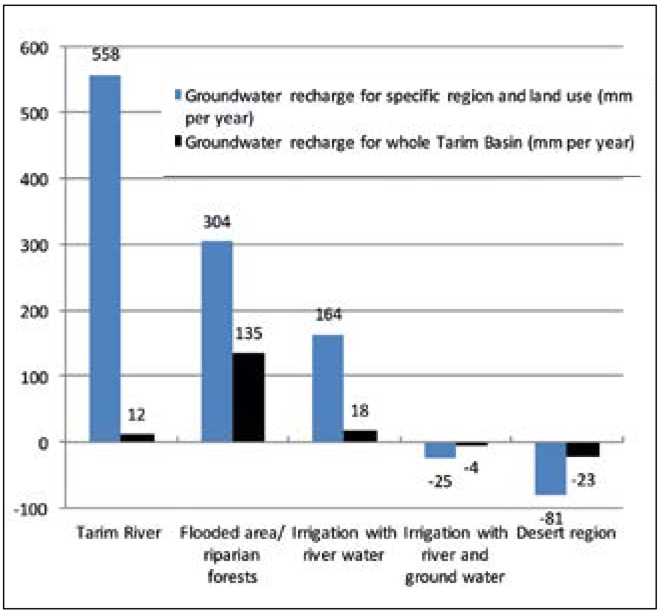
The highest groundwater recharge takes place within the Tarim River itself, followed by the flooded area and the riparian forest region. Looking at the Tarim Basin as a whole gives a different picture. The flooded areas and the riparian forests contribute the most – by far – to the total ground water recharge of the basin, and hence are a crucial component of an intact ecosystem.

In addition to water scarcity for the natural vegetation, a major problem is salinization of the intensively irrigated cotton fields. Therefore the interactions between large, continuous irrigated fields with various irrigation water sources (river water with low salt loads and pumped groundwater with high salt loads) and the natural vegetation along the river have been investigated focusing on:
- the impact of varying irrigation water origins on the groundwater levels, and the salinization of the cropland itself, as well as the surrounding natural vegetation; and
- the role of the natural vegetation during the natural flooding period in the summer.

The effect of irrigating cotton fields on the groundwater level, and salt concentration in the irrigated area as well as in neighbouring natural vegetation, was explored by using a groundwater model in MIKE SHE. Irrigation can originate from groundwater (despite it being forbidden) or from the Tarim River. These two water sources have different effects on the groundwater, and therefore on the neighbouring natural vegetation (Figure 2.32).

In cases where groundwater is pumped for irrigation, water is taken from the same small groundwater system and is applied to the upper topsoil, where evapotranspiration leads to loss of water

Figure 2.31: Annual recharge (positive values) and discharge in mm (negative values) from different regions and land uses in the middle reaches of the Tarim Basin (83.3 km²; Keilholz 2014, Huttner 2015).



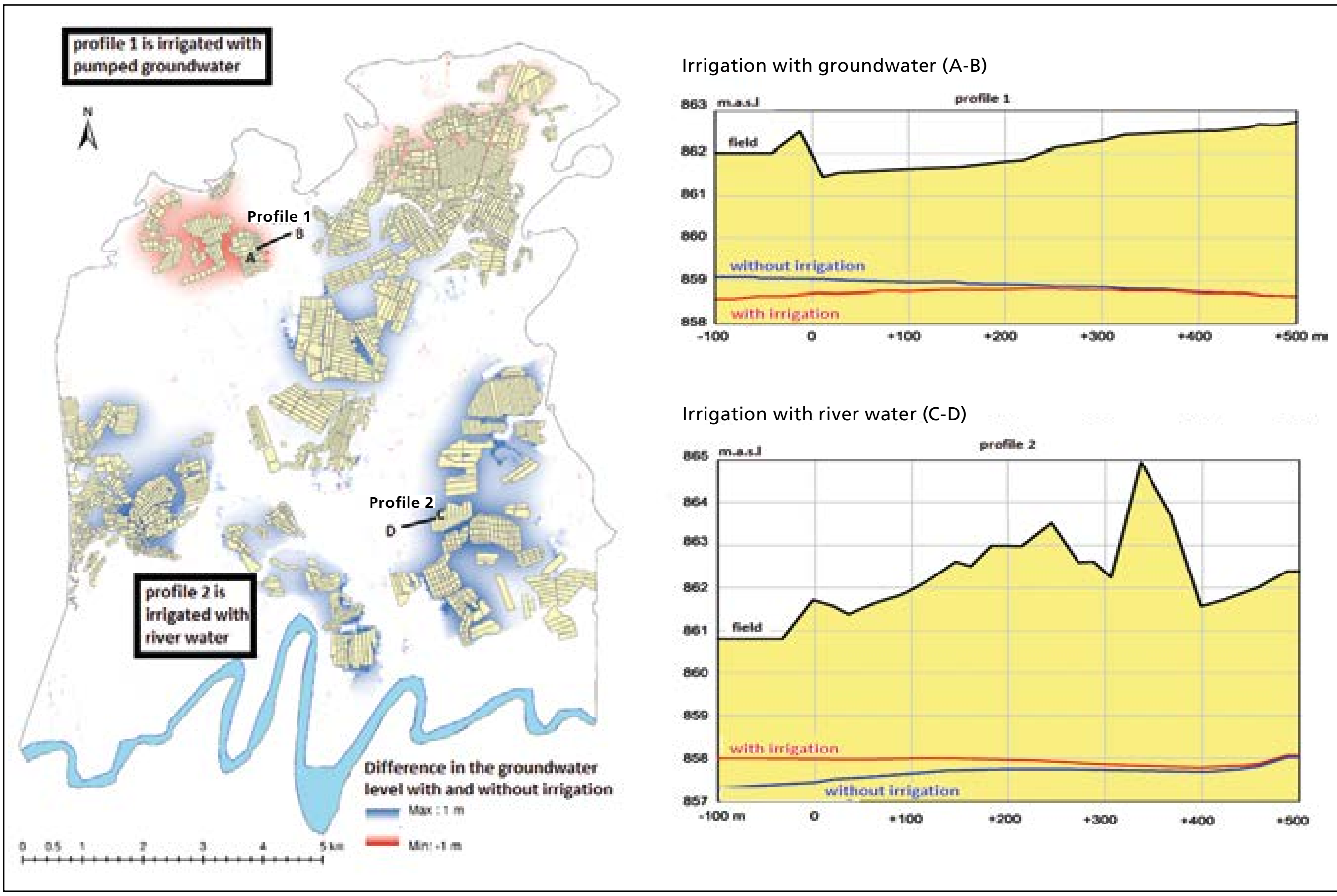


Figure 2.32: Groundwater table changes through irrigation along the Tarim River, China (September 2012). Red dots near profile 1 indicate a lowered groundwater table in and around the field irrigated with groundwater, which is pumped from the saturated zone under the field. Blue dots at profile 2 indicate a higher groundwater table for a field which is irrigated with additional river water. This difference in groundwater level is highlighted again in the cross-sectional view of the two profiles in the right of the figure (Keilholz 2014).

affecting the overall water balance, and the groundwater flow gradient is directed to the fields. Linked to this groundwater gradient also, salt loads from the surrounding area, which is covered with natural vegetation, are mobilized and transported below the field. The increased evapotranspiration, which is enhanced by the fine texture soil and the high groundwater table, leads to intensive accumulation of salts under the field. If water from the Tarim River is applied for irrigation, additional water is added to the local groundwater system, and therefore a groundwater flow gradient from the field to the surrounding area evolves and the salts are flushed to deeper soils and to the surrounding area, which leads to unfavourable conditions for the natural vegetation. This process is illustrated in Figure 2.33.

Table 2.3: Summary of the effect of the differing sources of irrigation water on the groundwater level and the salinization at different distances to the irrigated field. Red arrows indicate undesirable effect; green arrows indicate desirable effect (Keilholz 2014).

Source / Impact on	Irrigation with river water (profile 2)	Irrigation with groundwater (profile 1)
Groundwater level (in irrigated and surrounding areas)	↑ (green)	↓ (red)
Salinization of irrigated area	↓ (green)	↑ (red)
Salinization of surrounding area (natural forests)	↑ (red)	↓ (green)

The two dimensional effect in the distance and the depth of the field is even more surprising. For profile 1 the pumped groundwater results in the fact that salts are mobilized around the field, where the natural vegetation exists, and is transported towards the field. There the salts accumulate markedly under the field. For profile 2, an adverse effect can be observed where the salts are transported from the field towards the surrounding soils under the natural vegetation (Table 2.3).

Accordingly, two management solutions were identified:

- Currently there are large areas of continuous fields. A better management practice would be to integrate smaller agricultural fields and natural vegetation. In such a mosaic, the natural vegetation benefits from the irrigation water. As an additional benefit, smaller non-continuous irrigated areas leave more space for natural vegetation. Those areas function as natural flooding zones during the summer floods caused by discharge peaks of the Tarim River, and thus contribute to the necessary groundwater recharge.
- By applying good irrigation management, the combined use of river water and groundwater for irrigation can minimize the negative effect on the surrounding natural vegetation. For example, if the irrigation during the vegetative period in the summer is through groundwater, the inundation of the fields in the winter and spring (using stored water from the reservoirs) should be done by river water to recharge the groundwater, and thus lower the salinity.

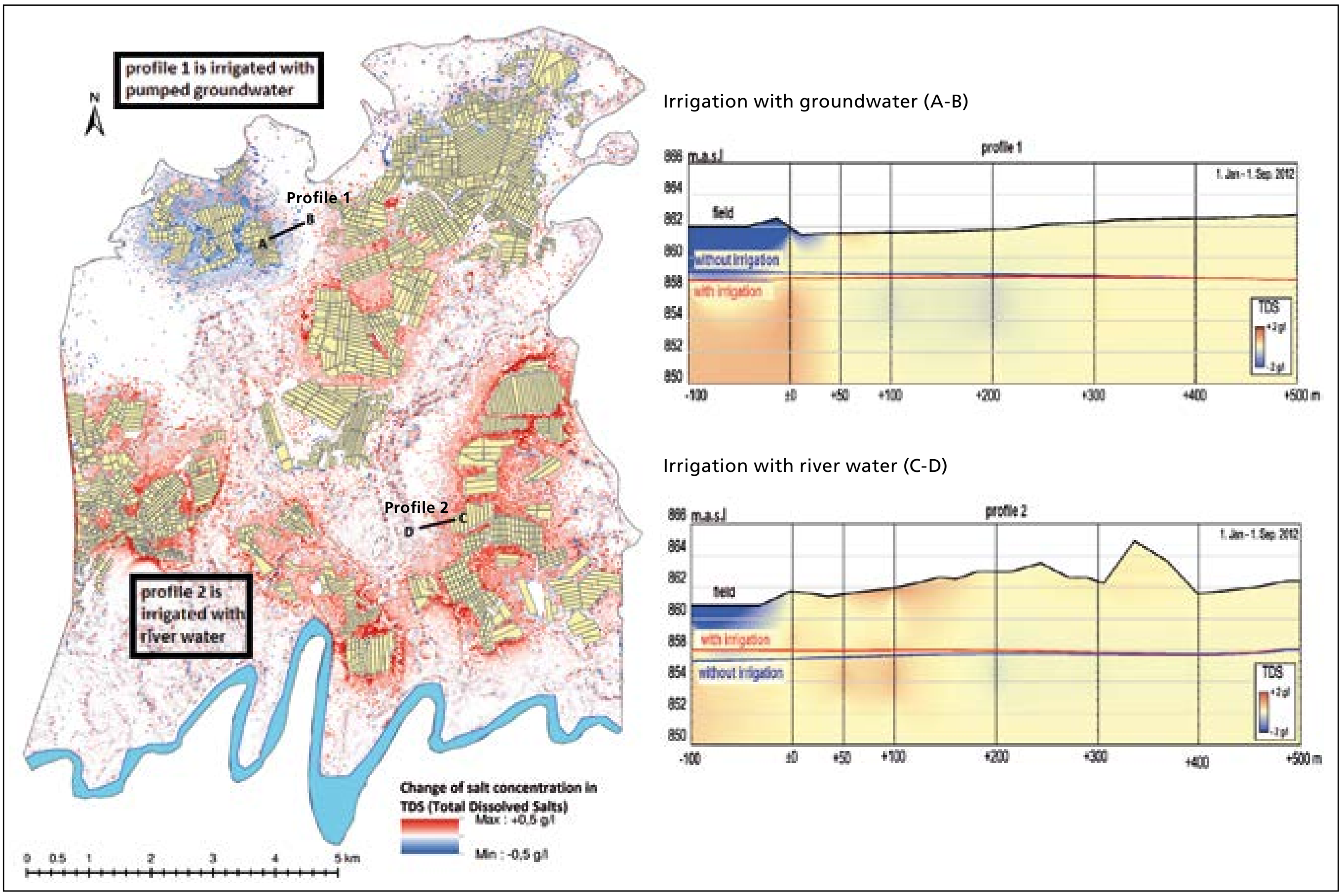


Figure 2.33: Salt concentrations through irrigation (from 1. January to 1. September 2012) along the Tarim River, China. In profile 1 (irrigation with pumped groundwater) the salt loads are transported from the surrounding area of several hundreds of meters and accumulate significantly under the field. In soil profile 2 (irrigated with river water), the salt loads under the field are pushed to the surrounding area, where the natural vegetation suffers. The cross-sectional view illustrates the positive and negative salt concentration changes, related to the different groundwater gradients, which are caused by the two different irrigation water origins (Keilholz 2014).

In this context, the function of riparian forests to recharge groundwater with less saline river water is even more important. An additional recommendation is to take some areas out of agricultural production, and thus irrigation, especially in the upstream part of the river. In addition to more water availability downstream, this would solve a chain of interconnected problems. Less irrigation overall would lead to lower groundwater levels and thus to a decrease in salinization, and consequent abandonment and wind erosion (see Chapter 1 page 28). The Chinese government is currently planning measures accordingly.

Water protection zones for springs and rivers in rubber plantations, China

Water protection zones and riparian buffer zones for improved water quality

context: improve the water quality in a rubber-tree dominated watershed

problem: decreasing quality of drinking water in intensely used rubber plantations, over-use of agro-chemicals

solution: integrated water management concept: water monitoring, capacity building, water protection zones (pollution partly due to erosion from plantations -> see Chapter 1)

message: the maintenance and improvement of riparian forests is important everywhere – but it can directly contribute to improved quality of drinking water in areas of intensive agricultural production

In rubber plantation areas in China's south-west province of Yunnan, water quality and availability are major issues. There are different perceptions of the problems by farmers, authorities and scientists. Farmers observe a reduction of drinking water quantity, particularly in the dry season, which they link to expansion of rubber cultivation. However, poor quality of drinking water is seen as a central problem rather by scientists and regional administration, while farmers do not perceive it a serious problem even if they report high turbidity after rain and 'rusty taste' of drinking water. As stakeholder workshops demonstrated this is primarily due to a lack of understanding of hidden health risks – especially those associated with pesticide overuse.

To improve water quality in a rubber-dominated watershed, like the Naban River Watershed in Yunnan, an integrated water management concept has been developed. Key components of the concept comprise water quality and quantity monitoring, capacity building workshops concerning the understanding of interactions between land management practices, pesticide application and water quality.

Water quality monitoring showed that, especially after rainfall events, turbidity as well as concentrations of microbial pollutants and agricultural chemicals (nitrogen, phosphorous, pesticides) are increased. Promising measures to avoid hazards to humans and the environment are increased vegetation cover to reduce erosion in the rubber plantation (see Technology 'Native trees in rubber monocultures' page 191 and Chapter 1 page 28 Figure 1.26) and the establishment of water protection zones and riparian buffer

Figure 2.34: Collection point for surface water: the common way to secure water supply for villages, China. (SURUMER)

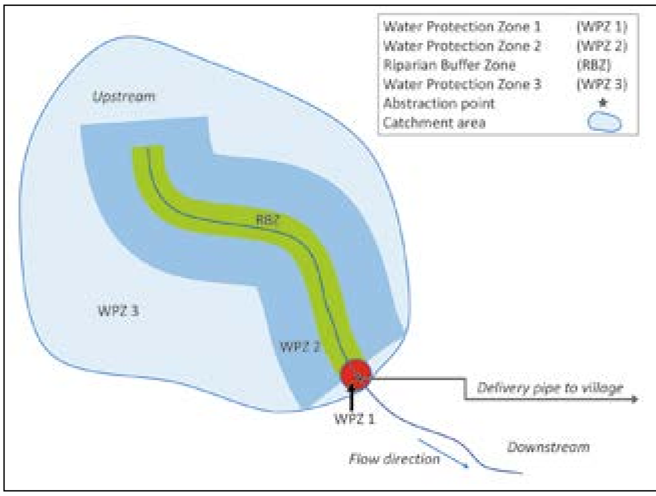


Figure 2.35: Water protection zone (WPZ) concept for a rural mountainous area in tropical South East Asia – Surface Water. (Krauss 2016)

zones (see Figure 2.35). In regard to drinking water quality, this is particularly important because non-treated surface water is used as drinking water in this region (Figure 2.34).

To protect water quality and quantity, a water protection zone surrounding the water source of each village can be established. The main objective of the Water Protection Zone Concept is to minimize anthropogenic and natural hazards and risks, which could lead to the deterioration of the water resources within the catchment area of drinking water abstraction points. This is achieved by avoidance of contaminants and enhanced natural attenuation of contaminants, and results from a set of different regulations, land use and land management restrictions, capacity development, awareness-rising and further measures. As a result, expensive and complicated end-of-pipe water treatment can be avoided or reduced (Krauss 2016).

Special attention has been given to developing riparian buffer strips and the 'water protection zone concept' in accordance with local regulations and management strategies (Figure 2.35). For example, reduced chemical weeding in rubber plantations leads to reduced runoff and soil erosion, and hence a lower sediment supply to water pathways (see Chapter 1 page 28 Figure 1.25). In combination with intercropping trials in rubber plantations, these experiences are being used to define the width of different protection zones and to develop specific management measures. The 'water protection zone concept' consists of four different zones: three water protection zones and one riparian forest protection zone. This helps to balance the local socio-economic trade-offs.

The purpose of the core zone/ Water Protection Zone 1 (WPZ 1) is to protect the abstraction point/ water spring against direct pollution and access by animals and unauthorized persons. This area should be fenced within a radius of 20 to 50 meters around the abstraction point. The second zone (WPZ 2) allows low-impact agriculture, without use of agrochemicals. This zone is larger than the core zone, and aims to stop deforestation in order to decrease soil erosion. The third zone (WPZ 3) covers the largest area around the water source. In this zone, specific pesticides, heavy metals, industrial chemicals or radioactive substances are prohibited, high erosion agriculture is restricted as well, but use of fertilizer is allowed.

The Riparian Buffer Zone is located within WPZ 2. It expands to at least 20 meters on each side of the stream, and natural vegetation reduces the input of solids, organic matter and contaminants. Further measures to protect riparian forests and water quality are:

- capacity development and awareness-raising workshops e.g. on the use, impact and fate of agrochemicals, and on intercommunal cooperation;
- acquisition of necessary land by the water supply utility;
- financial incentives to encourage farmers to change to agricultural practices which have less negative impacts on the drinking water quality

Measures to restore water-environment interactions, São Francisco Watershed, Brazil: The role of water user associations

Water user associations and community-based management to 'revitalize' the watershed

context: protecting springs and controlling erosion, effectively contributing to increasing the quantity and quality of water

problem: degradation within the watershed, 'reservoir comes first', scarce water

solution: promote environmental awareness, soil conservation measures, reforestation of riparian forests, establish conservation areas/ buffer zones, PES

message: some actions in watersheds can be best planned and undertaken by water user associations, if appropriately informed and guided

For the large São Francisco Watershed in Brazil a participatory committee was formed in order to steer it: *Comitê da Bacia Hidrográfica do Rio São Francisco* or (CBHSF). Among other matters, the CBHSF promotes the restoration of degraded areas to create alternatives for environmental preservation (Figure 2.36). The primary objectives were the protection of springs and control of erosion, effectively contributing to increasing the quantity and quality of water (Figure 2.37). Further objectives were renovating streets in order to reduce siltation of the water bodies through drainage, and adopting soil conservation measures. The measures were selective and had a demonstrative character (to promote environmental awareness), and were not linked to broader policies or programmes.

The process begins with citizens suggesting new projects, which were then discussed and decided in regional, technical, and plenary sessions. The committee, via its executive agency, issues public calls for tenders. The cheapest wins. The agency contracts one company for assessing the situation and preparing a project plan, another for executing the works, and a third for inspecting the works.

Figure 2.36: Newly completed conservation area fenced-off from livestock and people São Francisco Basin, Brazil. (http://cbhsaofrancisco.org.br/o-cbhsf/)

Figure 2.37: *Barraginha* – small pond for rainwater harvesting and control of sediment in the Bahian city of Cocos. (http://cbhsaofrancisco.org.br/cbhsf)

The projects were paid via water fees. Since 2010, water users who take up more than 4 l/s from the watershed's main river – the São Francisco River – are required to pay for their right to use water. The implemented measures involved the reforestation of riparian forests, in particular with native species, around springs, headwaters and along river banks. Engineering works include the fencing of springs and conservation areas, the building of terraces and contour banks, and constructing street gutters, rainwater retention basins and speed bumps. One project included payments for ecosystem services (PES). Workshops with neighbouring communities were part of the projects' method of discussing aims and progress. Signboards complemented information and awareness-raising. About 30 single projects have been completed within five years all over the watershed, and new ones initiated.

The committee and their implementation of the projects faced challenges. First, measures were undertaken by companies with little specific knowledge; works did not fulfil the goals or were even counterproductive – for example fencing-off not only of livestock, but also of wild game from access to water. People also criticized the fact that only registered companies were awarded contracts while informal local groups might have been better prepared for performing the tasks. Another concern was the small-scale of the measures, leaving doubts about their overall effectiveness. Finally, completed projects were inaugurated, while a monitoring and maintenance plan was not put in place.

2.3 Coastal zone management and ECO-DRR

For landscape management, another special zone within river catchments is the coastal zone. In two very different contexts, a strategy for ecological disaster risk reduction (ECO-DRR) has been developed as a cost-efficient solution to protect the coastline from erosion, and as an adaptation strategy to climate change:

- Realignment of the flood protection and land use change of northern Germany
- Protection of sand dunes and mangroves in the coastal zone of Vietnam

Realignment of the flood protection and land use change of northern Germany

Flood prevention of Germany's low coastal zone

context: Due to climate change more water in autumn and winter (increase of water table and water to be discharged to the sea), less water in summer and sea level rise are projected. Sea level rise will prevent effective discharge of excess rain water during winter. Different adaptation measures are being tested on the North and Baltic Sea coasts

problem:

- increased inland-water levels in winter and increased salt water intrusion in summer
- salinization of groundwater and ditch water

solution: creation of water retention and storage capacity, and water management measures to adapt (multifunctional landscape)

North Sea: water retention areas (polders) to buffer water levels during the year -> lower costs for pumping, lower risk of floods and salt water intrusion (but need to take land out of intense production); during the summer the retention area water can be used to increase pressure against salt water intrusion and dilute ditch water in the drier summer season

Baltic Sea: realignment of areas for reed cultivation (C-storage) and as a buffer; extensification of land use to pastures with salt tolerant plants

message: coastal zone management will become an increasing problem with climate change and sea level rise, range of measures will be needed to tackle this problem and needs to be planned as soon as possible

Within Germany's coastal lowlands, future water and land management is expected to be threatened by the following climate changes and related impacts: (i) more precipitation in autumn and winter, and extreme rainfall events causing increasing floods as the excess water cannot be drained and discharged rapidly enough to the sea, (ii) the sea level rise will hinder the natural discharge of the freshwater to the sea, and salt water intrusion will increase salinization of the soil and the groundwater, and (iii) drier summers will increase water stress in agriculture. The combination of rising sea levels and the greater quantities of water that need to be drained and discharged to sea, will mean that the current pumping capacity to drain the lowest part of the coastal area (near to, or below sea level) would have to be increased at high costs.

For the period of 1971 to 2100 Figure 2.38 illustrates the amount of rainfall, water use by evaporation of the water surface and transpiration by the vegetation and the water that can be naturally discharged during periods when the sea water level is lower than the level in the retention area and the amount that needs to be pumped into the sea. The prediction for the future is based on a medium scenario of climate change (A2) with a medium level

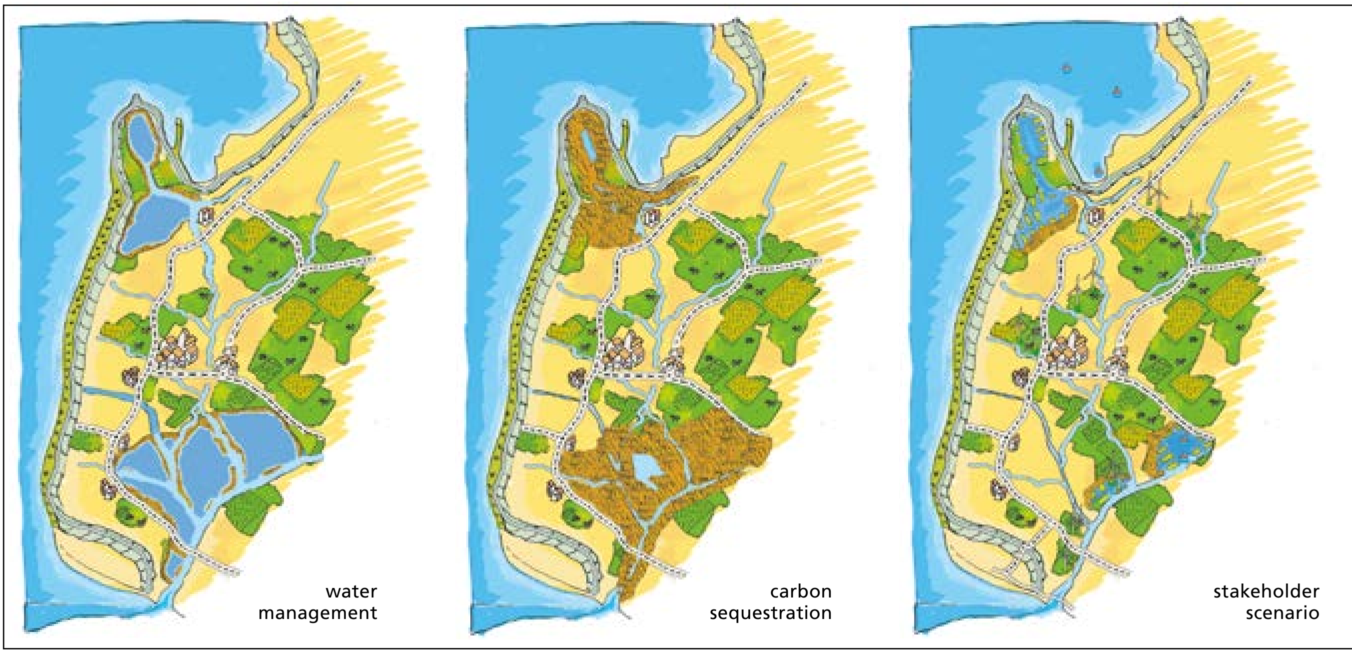


Figure 2.39: Illustration of maps for different scenarios for the North Sea coast, Germany: left 'water management' (adapted land use), middle 'carbon sequestration' (without agriculture) and right the 'stakeholder scenario' (improved water management). (COMTESS 2016, Udo Schotten)

of sea water rise (0.8m). The graph shows a trend with increasing rainfall, slightly increasing evapotranspiration due to increase in temperature but a clearly decreasing natural drainage and discharge of the inland water into the sea.

The result is a strongly increasing amount of inland water that needs to be pumped up to the sea level requesting increasing pumping capacity and costs (trend scenario, red line). Under the scenarios water management and carbon sequestration, where large areas will be reserved as ponds or lakes for water retention, the pumping will be reduced (orange line, Figure 2.39 left and middle, see Technology 'Polders without agriculture' page 219 and Video). If some of the lowest inland areas can be flooded during the highest rainfalls and the drainage ditches are broadened then the quantity of water that needs to be pumped can be reduced even more (purple line). This is the scenario the stakeholders proposed during meetings for planning adaptions to climate change. The scenario developed by the stakeholders assumes that the lowest areas are flooded during the high rainfall periods in spring with broadened ditches and this would reduce the volume to be pumped to almost one third of the amount under current management (Figure 2.39 right, see Technology 'Polders to improve water management' page 215 and Video).

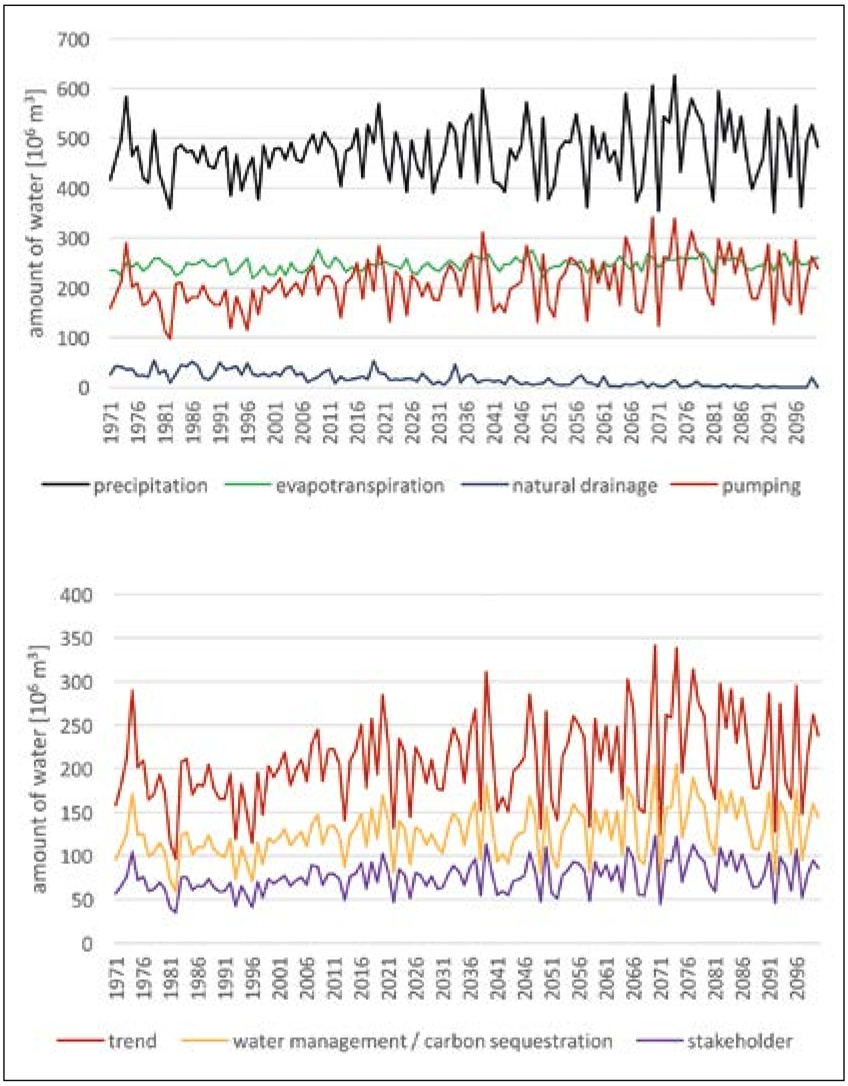


Figure 2.38: Rainfall (black), evapotranspiration (green), natural drainage (blue) and amount of water to be pumped from 1971 to 2100 (red) assuming a medium scenario (A2) of climate change and sea water level rise of 0.8m for the business as usual ('trend') scenario in red (top). The volume of pumping under two scenarios, the carbon sequestration scenario with a large water retention area and the stakeholders' choice of reserving the lowest areas for flooding is shown in orange and purple (bottom), North Sea coast, Germany. (COMTESS 2016)

Figure 2.40: Flooded coastal lowlands due to heavy rainfalls in Krummhörn, North Sea, Germany. (Jan van Dyk)

The coastal zones of the North and Baltic Sea have different characteristics. The low-lying areas of the North Sea are protected by a massive sea wall (up to 9 m high) against storm surges. The mainland is drained by a dense network of rivers and ditches to make agricultural land use and settlements possible (Figure 2.40). At the Baltic Sea coast, the tidal influence is not so great and small embankments are sufficient to protect the narrow band of below-sea level coastal land.

Even though the baseline conditions of both coastal regions are very different, the impacts of climate change will have similar consequences. Therefore, various measures to deal with these impacts can be examined in both regions and the transferability of the results tested. For example, on the North Sea coast, the development of water retention areas in mainland areas, lying under sea level, to avoid uncontrolled inland flooding is a new approach and might be a solution. For the narrow strip of below sea level areas on the Baltic Sea region, 'managed realignment' is an approach that can increase resilience against climate change. Managed realignment means that the existing embankments will be opened to allow a more natural dynamic of water flows, and the development of areas influenced by the water levels of the Baltic Sea.

Along the Baltic coast, an increase in pressure of saline groundwater due to sea level rise is expected. Saline groundwater reaches further landwards from the coast. This leads to salinization of ditch water. Ditch water is used by cattle for drinking. On the North Sea coast, a clay layer prevents the rise of saline groundwater in most areas. But at some spots peat layers enable saline groundwater to rise. On the Baltic Sea coast there is no clay layer to prevent the influx of saline groundwater in the embanked coastal sites. For the peninsula of Michaelsdorf the increased influx of saline groundwater is shown in Figure 2.41.

Construction of water retention areas enables storage of excess freshwater in autumn and winter, to reduce flood risk in coastal lowlands caused by heavy rainfall. During the dry summer periods, the stored freshwater in the retention areas can be used for irrigation – and to dilute saline ditch water. The stored freshwater also acts as a counter-pressure against saline groundwater from the sea. In the higher parts of the managed realignment areas on the Baltic coast, with lower flood risks, a change in land use from arable fields to pastures increases resilience against salinization. On coastal grasslands there are many plant species adapted to saline groundwater and flooding with sea water. The salt grasslands can be used for grazing or forage production. Flooded areas with brackish water can be used for reed production (Box 2.4).

During the wetter winter periods, the retention areas store excess water to prevent flooding of inland areas and reduce the amount of freshwater that needs to be pumped into the sea (see Chapter 3 page 86).

The simulation of different climate change scenarios included changes of runoff and water discharge (due to higher rainfall amounts and extreme storms) from the land towards the sea and the expected sea level rise, which reduces the time the water can discharge naturally into the sea. Within the water retention areas, and on sites with managed realignment, agricultural land use is adapted to higher water levels and possible flooding. Within these

Figure 2.41: Simulation of salt concentration on the peninsula of Michaelsdorf (Baltic Sea, Germany). With increasing sea levels, the salt concentration on the peninsula increases. The highest salt concentrations in 2010 are close to the sea and are expected to spread to the central parts of the peninsula by 2100. (COMTESS)

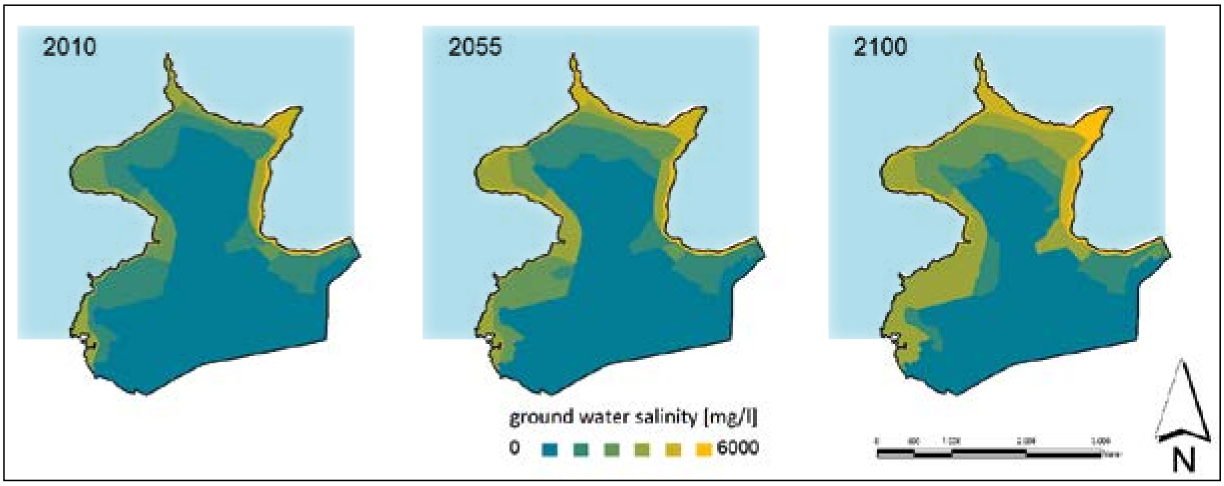


Figure 2.42: Identification of native tree and shrub species in a dune area in Central Vietnam. (Udo Nehren)

Figure 2.43: Planting mangroves to protect coasts: associated with people's life development in Vietnam. (LUCCi)

areas, the current intensive grazing for dairy farming and cropland production will be changed to extensive grazing, open waters and wetlands covered with reeds. With changed land use within the water retention area, the landscape is transformed from a mono-functional landscape to a more resilient multifunctional landscape (see Technology 'Polders without agriculture' page 219 and Technology 'Polders to improve water management' page 215 and Video). The new land use and management of the lowlands is less vulnerable to risks, requires reasonable investments to establish, but creates new opportunities for productive and protective systems, including opportunities for recreation, nature conservation and tourism. These land management systems are the proposed alternatives to huge investments to adapt the drainage system to increasing water levels. However, there will always be a trade-off with production and agriculturally productive land.

Box 2.4: Natural reeds as an alternative production for various purposes

Natural reeds in brackish water produce comparable amount of biomass to that obtained from maize cultivation (in mown reed stands in north-western Germany: 13 tonnes of above-ground dry mass per hectare per annum; in mown reeds: 15 tonnes of above-ground dry weight per hectare per annum). In contrast to maize cultivation there is no need to invest in soil cultivation, sowing, fertilization or crop protection. Reeds can be used for direct combustion, to obtain biofuel, or in biogas plants. Besides this, use of reeds in the industrial sector is also possible (insulation panels etc.). Further usable applications of reeds are currently being intensively researched (COMTESS).

Ecosystem-based disaster risk reduction and adaptation in coastal zone of Vietnam

Protection of sand dunes and mangroves in coastal zones of Vietnam

context: reduce the risk of coastal hazards and adapt to climate change

problem: destruction of protective natural coastal zones (sand dunes and mangroves) through land use change

solution: awareness-raising and enforced coastal protection (mix of measures)

message: coastal ecosystems are coming under threat throughout the tropics and elsewhere, and action is necessary – for example to re-establish mangrove forests – but alongside this there is an urgent need for awareness-raising

Along the coast in Vietnam, ecosystem-based disaster risk reduction (Eco-DRR) and adaptation (EbA) are considered suitable strategies to reduce the risk of coastal hazards and adapt to climate change. The potential of dune systems (Figure 2.42) and small mangrove remnants (Figure 2.43) for coastal protection in Quang Nam province (project research area) is summarized in Table 2.4.

Table 2.4: Ecological status and recommended Eco-DDR/EbA measures for coastal dune systems and mangrove remnants in the coastal zone in Quang Nam province, Central Vietnam

Ecosystem	Ecological Status	Recommended Eco-DRR/EbA measures
Coastal dunes	Medium to high degradation due to: (a) replacement of native vegetation by non-endemic monocultures such as casuarina and acacia species (b) agriculture and aquaculture activities; (c) infrastructure development; (d) sand extraction; (e) waste disposal	(a) Establishment of awareness-raising and environmental education for coastal population on the multiple ecosystem services coastal dune systems provide; (b) Enhanced implementation of environmental legislation so that coastal forests on sandy shores are designated as 'Protection Forest' (c) Monitoring of land use changes in the coastal zone, as large stretches of coastal dunes are still being converted into agricultural land or shrimp ponds, and sand extracted for construction purposes; (d) Development of community-based restoration and conservation programmes including afforesting measures with native trees and shrubs; (e) Provision of financial incentives for coastal communities to actively support coastal dune conservation
Mangroves	Very high degradation status; most mangroves have been lost and the few remaining remnants are small and highly degraded due to wood extraction and waste deposition	Large-scale restoration of mangroves is difficult, due to land use pressure (infrastructural development, intensive land use). Suggestion: Improvement of ecological status and connection of remaining remnants. Community-based restoration programs of native species should be developed and supported by government and development/ aid projects. To achieve good protection against typhoons, a mangrove belt of at least 200 m width is recommended.

Conclusions

Overall challenges and opportunities

The growing demand for more land and water for agricultural, industrial and urban use and further societal claims are leading to changes in land use and management alongside challenges to find appropriate SLM practices that deliver services for people. These include changes:

- Within the main land use systems – often non-sustainable intensification.
- Conversion of natural and semi-natural land into agriculture and the conversion of agricultural and natural land into settlements, infrastructure and urbanization.
- Upstream land use and management affecting or conflicting with downstream uses.

What is required includes the following:

- Acknowledging the multiple demands on land and its resources while attempting to reconcile the various claims.
- Recognising both synergies and trade-offs between local and regional or landscape interests and potentials: interactions and interdependencies must be acknowledged and accommodated in planning and management.
- Limiting expansion or reducing the area where a particular land use is causing problems and has negative impacts.
- Taking into account water availability and quality – which consistently affects land use and management (and vice-versa).
- Using opportunities and rewards for carbon mitigation and biodiversity protection.
- Reducing disaster risks through landscape management that recognises climate change impacts while assigning space for different purposes and services provided.
- Using scenario building and modeling impacts as a knowledge-based tool that can deal with complex interactions and processes related to land management and its impacts. Results provide the basis for negotiation and informed decision-making.
- Utilising research – not just for analysing problems and developing model based recommendations – but as neutral arbitrators within this stakeholder landscape.
- Above all is the need for better cross-sector cooperation and coordination through integrated landscape management. This is a core part of sustainable development: while not new, it needs to be repeated – and put into action.

River Basin management

Within river basins, watershed or catchments the dependency between upstream and downstream resource users is very high. The key connecting agent between upland and lowland systems is water: its various facets remain a key area for research. Management is very complex as it must connect various scales, stakeholders and interests with numerous interactions and dependencies. A main concern is that upstream land use can cause either too much water flow in the lowlands or too little:

- Too much caused by inappropriate land management upstream resulting in high runoff, erosion and floods and sedimentation downstream.
- Too little when upstream overuse of river water for growing demands for irrigation or hydropower causes water shortage downstream (or diminishes the water quality).
- In addition, climate change is leading to changes in rainfall and temperature: increasing rainfall or decreasing rainfall or prolonged dry and hot spells, droughts which causes new/additional challenges. For all further research projects, the key challenge will be to project and explore options for the future as both climate and land and water management are changing.

The opportunities that have been identified are as follows:

- Development of an overall management plan involving all water users, and uses, to plan and regulate water distribution and land use. Adapt the plan continuously.
- Improved governance of hydropower and irrigation water management.
- Improved land management to cope with extreme rainfall events and store the water in the soil or excess water in reservoirs in upstream areas.
- Developing water storage systems and managing them effectively (including reservoirs and barrages/ weirs).
- Use of water efficiently during dry periods in both rainfed (e.g. conservation agriculture no-till, minimum tillage, agroforestry, intercropping etc.) and irrigated land (e.g. re-using return water).
- Choice of land use according to available water (e.g. no high water demanding crop production in areas with water scarcity to reduce water demand for irrigation).

Riparian forest and water quality

Water quality is decreasing in several of the regions from within agriculture (agro-chemicals) as well as from the outside (salt water intrusion, eutrophication). These problems often increase with water scarcity. Indirect water pollution, coming from inappropriate land use needs to be identified and quantified in order to develop appropriate countermeasures. Pollutants mainly come from (i) soil erosion and agro-chemicals – including fertilizers which lead to eutrophication of rivers, reservoirs and groundwater, and (ii) irrigation drainage or return water polluting water bodies leading to eutrophication or chemical pollution.

The opportunities identified can be summarised as:

- Erosion reduction through better local land management.
- Adapted irrigation management preventing salinization of soils.
- Protection of riparian forests and vegetation, as well as water protection zones.
- Protection and rehabilitation of coastal ecosystems, including mangrove forests.

Coastal zones

Major changes in water use and management within river basins due to hydropower and over-abstraction as well as major changes of land use may lead to lower flow to the coastal regions during the dry seasons and higher peak floods during the rainy seasons. Climate change leads to rising sea levels, and changes in seasonal rainfall patterns, and climate extremes and/or land management cause:

- Increased flooding due increased rainfall and extreme events.
- Salt water intrusion due to reduced river flow in the dry seasons due to over-abstraction of the river water for irrigation.
- Salt water intrusion in rivers or lowlands and in the groundwater due to increased sea level (in combination with above).
- Opportunities identified and principles for improvements:
- Regulations and agreements between upstream and downstream users guaranteeing a minimum dry season flow.
- Creating flood retention areas to temporarily store freshwater and release it during dry seasons and low flows, simultaneously preventing rise of saline groundwater.
- Hindering salt water intrusion by blocking sea water flow into rivers during low flows, reducing ground water use and abstractions from the rivers.
- Ecosystem-based disaster risk reduction (Eco-DRR) to protect the coastal zone from erosion, salt water intrusion and to adapt to CC.

To achieve significant impact, it is clearly evident that research must be implementation-oriented. However, research often lacks resources as well as cooperation from various stakeholders and sectors involved in river basin management – having different, and partly hidden, interests. Furthermore, even implementation-oriented research is a half-way stage in the overall process of transformational development. But it is a step in the right direction.

CHAPTER 3

Mitigating climate change

Brazil, Stefan Hohnwald

Introduction

Society can rightly claim how land is used in relation to climate change mitigation with its consequences of global warming and projected negative impacts on ecosystem services and on people. Various synergies and trade-offs of climate change mitigation measures have already been presented and discussed in the previous chapters. This chapter now focuses on the potentials of different land use and land management practices, in cases where climate change mitigation – especially carbon sequestration – was the primary goal.

Both soil and vegetation hold and store carbon (C). Carbon stocks and their dynamics are very diverse and depend on many factors. Land use change and the management of soil, water and vegetation can decrease these C stocks and by turning them into greenhouse gases (GHG) which are emitted into the atmosphere. Conversely, other practices increase C-sequestration (storage) above and below ground. In the first case, land becomes a 'C-source' and in the latter a 'C-sink'. Reducing carbon dioxide (CO_2) and other GHG emissions plays a central role in global efforts towards climate change mitigation.

The main factors determining GHG emissions, or mitigation of these, are land use and management, as well as type of soil, soil moisture content, groundwater levels, vegetation cover and climate. Generally speaking, there is a gradient from wetlands and forests with high C-storage potential, to pastures/ grasslands with medium potential, to cropland with medium to low potentials, and finally to settlements, with low GHG storage potential. Within these land use types there are differences in respect to GHG emissions depending on the specific management practice put in place. Despite these differences due to practices, the gradient between the land use types is the most important determinant. Thus, from a climate change mitigation perspective, it is most important to try to prevent conversion to a land use with lower C storage potential, and even to try to reverse land conversion wherever possible.

Different soil types have very different potentials for C storage. For each of them the variability is high, as illustrated from the Tyumen steppe of western Siberia in Russia (Figure 3.1).

In this region, the highest stocks are found in organic soils (Histosols) and the deep black ('black cotton') soils (Chernozems and Phaeozems). The black soils are suitable and valuable for agriculture due their high amounts of stored soil organic carbon (SOC) and the fertility that this confers. Croplands are mainly located on these deep fertile black soils. Other soil types are not fertile enough to be suitable for production. For example, the organic Histosoils are too wet for crop production. Forests and grasslands, however, grow on a large variety of soil types.

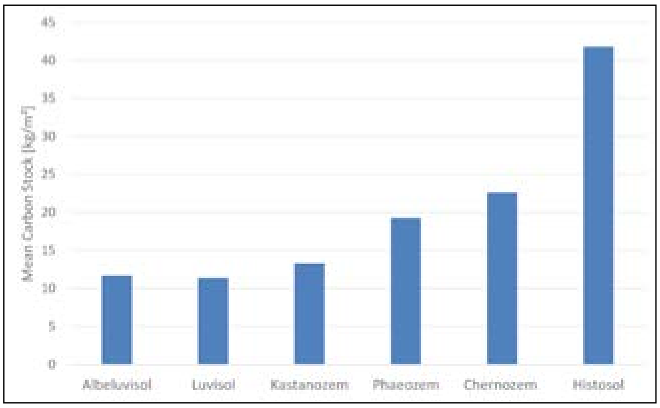


Figure 3.1: Mean carbon stocks in kg/m² for the major soil types in the Tyumen steppe of western Siberia in Russia (project data; kg/m² x 10 = Mg/ha). The mean value for Kastanozems is taken from Batjes (2002). (Tim-Martin Wertebach)

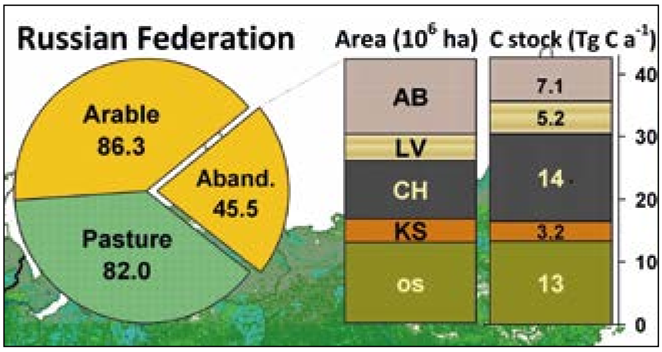


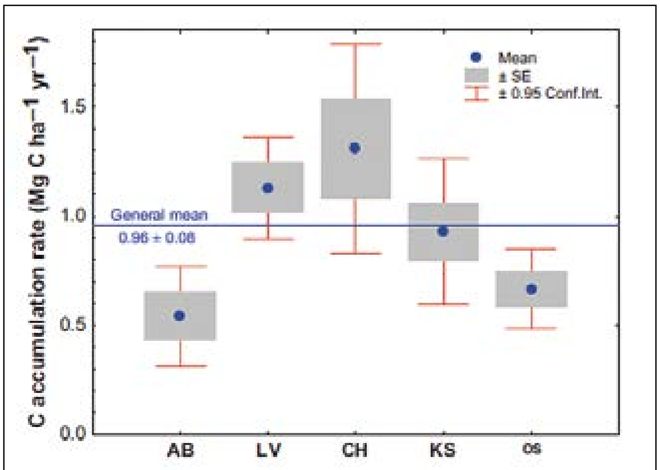
Figure 3.3: Categories of farmland in the Russian Federation and the contribution to carbon sequestration of abandoned croplands after the break-up of the Soviet Union. Albeluvisols (AB), Luvisols (LV), Chernozems (CH), Kastanozems (KS) and other soils (os); ha: hectare, Tg: teragrams, C a-1: Carbon per year (Kurganova 2014).

After the break-up of the Soviet Union, vast areas of cropland were abandoned, and as a result carbon sequestration took place because of the lack of ploughing and the consequent increase in natural vegetation. As illustrated in Figure 3.2, for each of the soil types given in Figure 3.1, different land management resulted in very different levels of carbon stocks. When cropland is abandoned and left for natural vegetation to grow, the accumulation of the carbon is highest for soils with the greatest storage potential (i.e. Chernozems) and this equates to relatively high mitigation of climate change. In addition, the highest level of carbon sequestration is found in the upper part of the soil profiles, and the amount of SOC stored there is positively related to the time since abandonment: the longer the fallow period, the more the carbon (Schierhorn et al. 2013; Kurganova et al. 2014).

The analysis for the whole Russian Federation shows that about one third of all arable land has been abandoned for 20 years, and that for the area abandoned the black Chernozems have built-up organic C the most (Figure 3.3). This demonstrates the potential of grassland preservation and grassland restoration. Thus, 'extensification' through the abandonment of cropland and its reversion to natural vegetation has a substantial capacity to build up carbon stocks.

How far Russia may be affected by future land use changes remains a matter of debate. Land use change to cropland will impact negatively on climate change. From this point of view, natural grasslands and peatland ecosystems should be preserved, as they have high organic carbon stocks and are very sensitive to altered management system (for example through drainage and ploughing; Batjes 2002).

Figure 3.2: Average carbon accumulation rates in five main soil groups in Russia for the first 20 years after abandonment of cultivation (1990-2009). There is a significant difference between the soil groups: Albeluvisols (AB), Luvisols (LV), Chernozems (CH), Kastanozems (KS) and other soils (os). Mg: megagrams, SE: standard error, Conf. Int. confidence interval (P<0.05). (Kurganova 2014)



Another factor determining whether land is a source or sink of C is the water level and its dynamics. Again, there are differences between soil types. Methane emissions (methane being a powerful GHG) and carbon dioxide sequestration in soils depend on the groundwater level, and soil properties – whether they are 'organic' or 'mineral' soils as illustrated from the North Sea coast in Germany (Figure 3.4).

In organic soils with low groundwater levels (- 40 to -100 cm mean annual GWL) high emissions of CO_2 occur (up to 40 t CO_2/ha/year). On mineral soils, very low CO_2 emissions take place with low water tables. With groundwater levels rising to less than 10 cm beneath the surface, or when the surface is flooded, carbon sequestration in soil starts and increases with increasing water levels in both soil types. In wet situations with water levels higher than 20 cm below soil surface, methane (CH_4) emissions increase and reach higher values in flooded areas (water levels 10-40 cm above surface). Methane emissions do not differ between organic and mineral soils. The 'Global Warming Potential' (GWP) shows the warming resulting from the sum of GHG emissions and carbon sequestration. For both soils, the ideal ground water level for minimising GHG emissions is 10 cm below the soil surface (-10 cm) although there still is a slight global warming potential due to the emissions that do occur. The variability of soil types, land uses and groundwater levels makes it difficult to assess and compare C-storage potential of different land use types and hence to come up with general and robust recommendations.

Highlighted by the research conducted in the BMBF-SLM programme, the following examples of climate change mitigation are classified:

- developing nationwide strategies for climate change mitigation;
- preventing conversion of land;
- reversing land conversion;
- restoring wetlands and organic soils; and
- reducing emissions from agricultural practices.

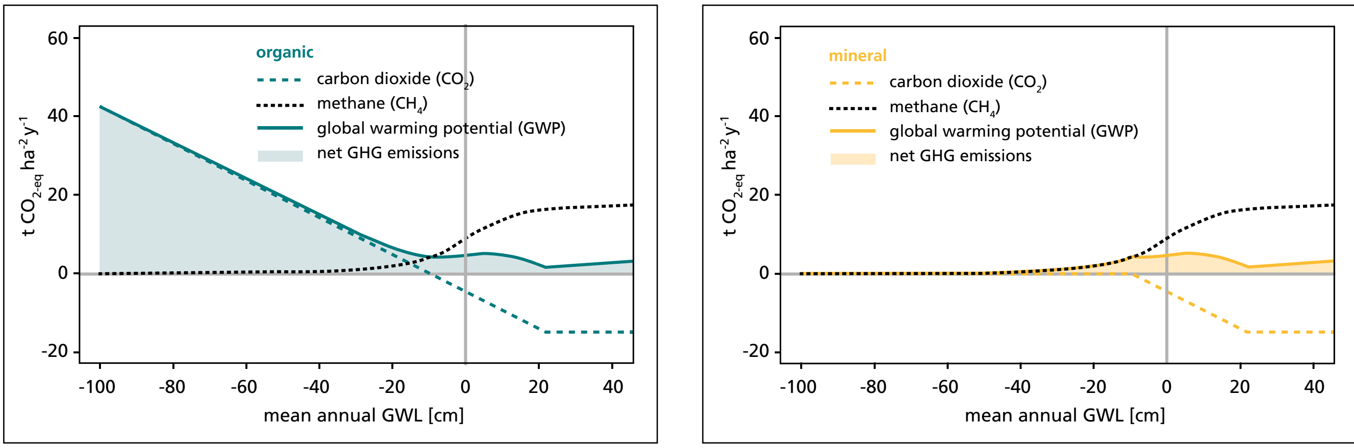


Figure 3.4: Generalized model of global warming potential (GWP) and greenhouse gas (GHG) emissions of organic (left) and mineral soils (right) as a function of mean annual ground water level (GWL), Germany. The emissions of the different GHGs are given in tonnes of CO^2-equivalents per ha and per year to make them comparable. (a) for organic soils (blue) and (b) for mineral soils (yellow). (COMTESS 2016)

3.1 Developing nationwide strategies for climate change mitigation

Climate change mitigation in Germany: optimizing conflicting demands

Stakeholder involvement and scenario building for climate change mitigation in Germany

context: development of national strategies for Climate Change-Mitigation (CC-M). The goal of the German Sustainable Development Strategy is to reduce conversion of land into settlement and transportation (GFG 2002)

problem: how to satisfy the multiple claims and societal demands on land while reducing GHG emissions? Current high level of land conversion to settlement, transportation infrastructure and crop land with impacts on GHG emissions

solution: based on modelling and scenario building, different combinations of CC-M measures and their impact were assessed and used to develop recommendations for future land uses and management

message: involve stakeholders in joint scenario building to help address conflicting demands

In Germany, there are many vested interests in land management, and a great number of stakeholder groups from agriculture, forestry and settlement, as well as transportation sectors at regional and national levels who compete for the limited resource of land. Land use conflicts occur when different actors address their own interests only regarding the utilization of one and the same area of land, or when stakeholders declare certain land uses as 'a problem' and aim to achieve land use changes or restrict or ban use all together. Stakeholders have different interests in land use, and their conflicts can be sectoral (within a certain land use: for example within agriculture) and/or cross-sectoral (between agriculture, forestry, settlements and transportation, and nature conservation). Conflicting interests also occur between different levels – namely local, regional and national interests.

The German national strategy for Climate Change-Mitigation (CC-M) illustrates many involved synergies and trade-offs between different land uses and management systems in view of achieving climate change mitigation and other societal preferences and multiple claims (BMUB 2014). To mitigate climate change implies a claim on land use by society at large. In order to achieve mitigation it is very important to reduce conversion of especially forests and grassland to settlement and transportation areas. The aim of the German government is to reduce the daily land loss to settlement and transportation from 74 ha in 2010 to 30 ha in 2020 (UBA-Federal Environmental Agency, 2004). In 2000 land loss was around 130 ha per day. Due to the complexity of processes under different land use, soil and water conditions it is important to assess effectiveness and efficiency of different measures, and to develop a suitable mix in order to reach the goals of CC-M without adversely affecting other societal preferences. Based on modelling, different combinations of CC-M measures were assessed according to their impact on GHG emissions. The intention was to develop recommendations for an optimal set of land uses and management.

The land use conflicts which emerged from stakeholders in Germany have been compiled and visualized, as a basis for negotiations between the stakeholders involved. Figure 3.5 illustrates the complexity of claims and conflicts for the national and regional level in Germany, and the challenge for research to come up with agreed scenarios for future development (Steinhäusser et al. 2015).

There are two types of conflicts: intra-sectoral and cross-sectoral conflicts which differ regionally. Cross-sectoral conflicts to be addressed at the national level are between the forestry and agricultural sector, mainly relate to the national law for (re)afforestation due to other use (e.g. settlement areas, roads) on agricultural land. Cross-sectoral conflicts also exist between the forestry and settlement and transportation (S/T) sectors, involving forest fragmentation or the new usage of forest for renewable energy production like wind turbines. Intra-sectoral conflicts include food versus animal feed production, and the additional demand on agricultural land for bioenergy production. At the regional level, the conflicts are multiple and occur also within and between sectors: between forestry and S/T including the reduction of forests due to recreation, tourism or gravel extraction, between agriculture and S/T – for instance changing the landscape through biomass production. Intra-sectoral livestock farming versus horse husbandry, and wind turbines versus quality of life were also mentioned by regional stakeholders. Figure 3.5 illustrates the complexity of claims and conflicts at the national and regional level for Germany, and the challenge for research to come up with agreed scenarios for future development.

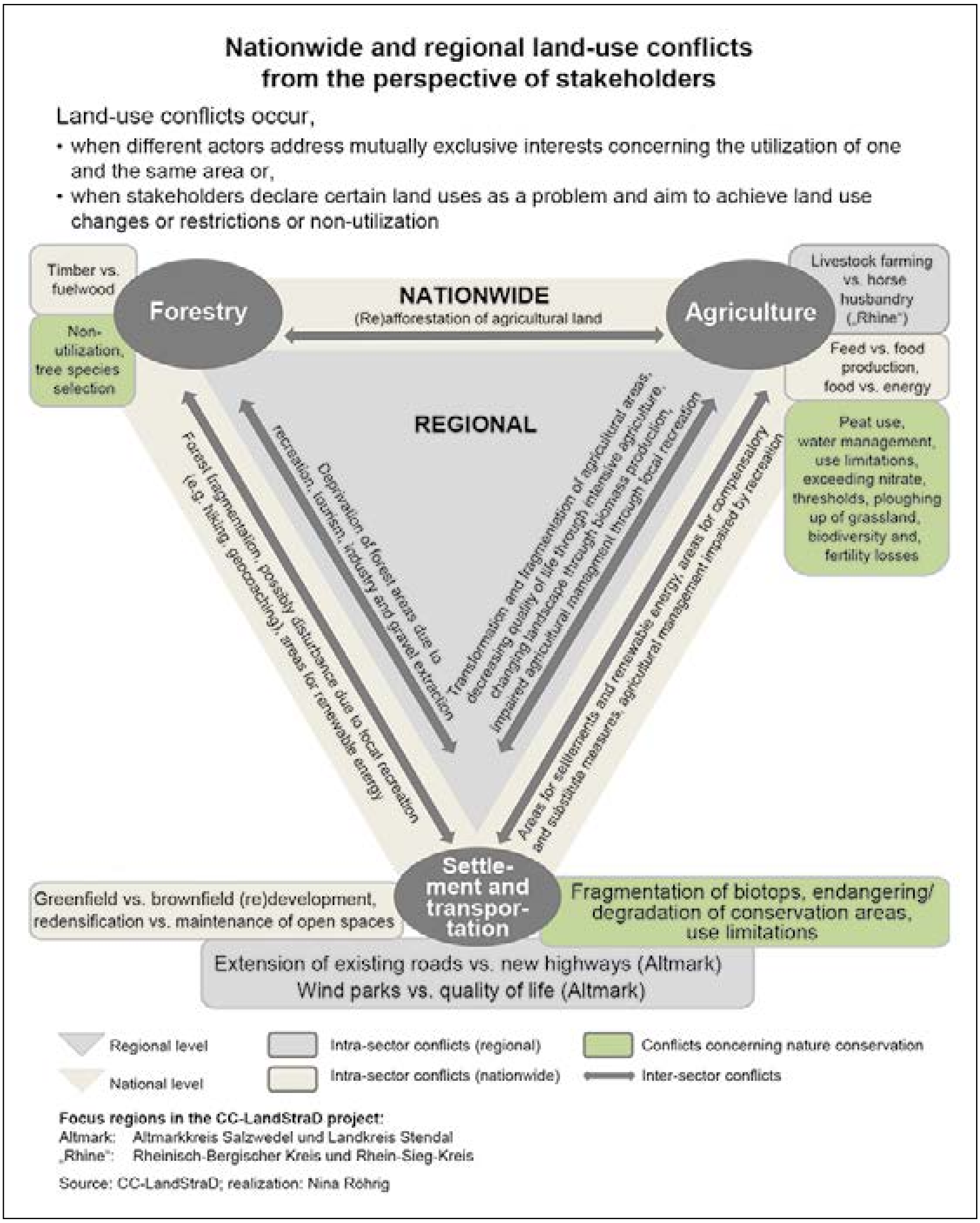


Figure 3.5: National and regional land use conflicts from the perspective of different stakeholders, Germany. (Steinhäusser et al 2015, Nina Röhring)

To overcome these conflicts, four land use scenarios termed 'strategies' were developed together with stakeholders. Each strategy consists of a mix of measures within the sectors involved, namely settlement and transportation (S/T), agriculture and forestry. The focus of these four strategies is either on: (i) climate mitigation, (ii) production of biomass for bioenergy, (iii) nature and environmental protection, and/or (iv) climate adaptation. In each strategy, the combination of the sectoral measures differs according to the strategy focus. Table 3.1 shows the measures available in the S/T and agriculture sectors that can be combined into an effective strategy in accordance with the overall focus.

The best measures identified in the scenarios to contribute to climate mitigation in Germany are high-quality inner urban development (see Technology 'Inner urban development' page 199), preservation of existing grassland (see Technology 'Grassland preservation' page 207), and adapted management of organic soils such as re-wetting, extensive grassland cultivation and high quality paludiculture (peatland preservation) (see Technology 'Adapted management of organic soils' page 203).

Decrease conversion through inner urban development

The business-as-usual scenario (implementing all politics and actions decided so far) shows that the share for S/T areas will increase until 2030 from 11.7% to 14%; compared to 2010, forestry will increase slightly from 30% to 31%; and agriculture will decrease from 52.3% to 50%. The daily 'consumption' of areas for S/T will decline from 74 ha in 2010, to 45 ha in 2030 (Goetzke et al. 2014, Goetzke and Hoymann in press). Through high-quality inner urban development, the daily conversion to S/T could be further reduced. The scenario 'climate mitigation', in which all mitigation measures are implemented, shows a potential decline of daily consumption of land for S/T use to 20 ha in 2030.

Settlement and Transportation (S/T) sector	Agriculture sector
Demolition and reduction of sealed surfaces	Use of organic soil: – Rewetting of peatlands – Adapted grassland use on organic soil – Paludiculture (peatland preservation)
Increase building density in new construction sites	Adaption of fertilizer/ manure management: – Increase of use efficiency of mineral fertilizers and N-utilisation from organic manure and slurry
Brownfield development/ reduce vacant lots	Replacement of fossil energy by bioenergy: – Cultivation of annual plants – Cultivation of perennial plants – Reducing maize cultivation
Changes in modal split (use of different transportation)	Use of grassland: – Preservation of grassland – When appropriate, conversion of arable land to grassland – Extensive use of grassland – Increase of the numbers of cuts of grassland
Strengthening of public transport	
Expanding priority and reserved function areas	
Development of urban green spaces	
Centralisation of settlement structure	

Table 3.1: Measures that can be implemented under different land use sectors and strategy foci illustrated using the example of the 'settlement and transportation' as well as the 'agriculture' sector. (CC-LandStraD)

Due to the effects of climate change and the high vulnerability of S/T areas to climate change (e.g. increase of temperature or heavy rainfall), measures to adapt to climate change were also considered, like more green and blue corridors in urban areas (e.g. areas facilitating wind circulation, water ponds, lakes, re-filling historic river beds: Figures 3.6 and 3.7). In the scenario that places the preference for 'climate adaptation' the daily conversion of land to S/T declines to 40 ha in 2030. With this strategy, the target of the German Government to reduce the daily land conversion to S/T areas to 30 ha in 2020 cannot be reached. In fact, the 30 ha target could only be reached by 2030, if all investigated measures for climate mitigation and climate adaption were to be combined.

Another consequence of land conversion to S/T is the decrease of areas with high quality soils for farming: these often border settlements. This leads to a decrease in land to produce food, animal feed, fibre or biomass for energy production and/or of areas for recreation, for biodiversity, and thus fewer areas to reduce GHG emissions etc.

Figure 3.6: 'Settlements and Transportation' and green spaces in Leipzig, Germany. (Dietmar Kabisch)

Figure 3.7: 'Settlements and Transportation' with green (e. g. parks) and blue (e.g. water bodies) corridors, Germany. (Johanna Fick)

Preservation of grasslands

Converting grassland to cropland enhances the mineralization of soil organic matter and leads to high emissions of the greenhouse gas carbon dioxide (CO_2) and, to a much lower extent, nitrogen dioxide (NO_2). Additionally, carbon losses during the first years of the conversion are much higher than carbon gains if cropland is converted back to grassland. It takes several decades to recover the organic matter that has been lost within a few years. Thus, wherever possible conversion should be prevented in the first place.

Re-wetting of organic soils

Re-wetting organic soils decreases the emission of CO_2 and NO_2 but during the first years methane (CH_4) emissions may be very high depending on the periods of flooding and the amount and degradability of crop residues. So, part of the GHG savings from reduced CO_2 loss might be outbalanced by methane emissions within the first years after re-wetting. Depending on the water table regulation, and vegetation it can take decades before the full mitigation potential of re-wetting is established. High water levels lead to methane emissions because microbial consumption of methane in an aerobic soil horizon is then impeded: thus water level management is crucial. Re-wetting to give a water level of 10 cm below the surface is considered ideal from a climate point of view, and prevents peat mineralization (Figure 3.8). Re-wetting 30% of the organic soils currently under agricultural use in Germany would reduce the GHG emissions from the agricultural sector by 8% (Henseler et al. in preparation).

Figure 3.8: Prototype harvester for re-wetted areas. In order to retain some production from the wetlands part of the biomass is removed. (Wendelin Wichtmann)

3.2 Preventing land conversion

The highest emissions from land use happen when land is converted:

- from forest to pasture or cropland, and from grassland to cropland through loss of carbon stored in the vegetation (especially forests), by erosion as well, through mineralization of organic matter, especially in the top soil because of surface disturbance;
- from wetlands to agricultural land by drainage and mineralization of the accumulated carbon stock in the soil organic matter (through oxidation: basically oxygen joins with carbon to form the greenhouse gas, CO_2);
- from forests, grassland, agricultural land to sealed soil surfaces in settlements and transportation by loss of carbon stored in the vegetation removed, and loss of capacity of the soil to sequester and store carbon.

The following examples illustrate options for preventing conversion:

- Woodland and riparian forest protection and sustainable intensification of agriculture in the Okavango Basin (Angola, Namibia and Botswana)
- Inner urban development to reduce land conversion in Germany
- Grassland preservation and extensive use enhancing biodiversity, Germany

Reducing forest conversion in the Okavango Basin

Woodland and riparian forest protection and sustainable intensification of agriculture in the Okavango Basin
context: conversion of forests and woodlands to fields for small-scale agriculture threatening the long-term provision of ecosystem function and services related to water regulation and biodiversity
problem: deforestation due to conversion into agricultural land and wild fires -> release of stored carbon in vegetation and soil
solution: prevent woodland conversion/ protect existing forests and wetlands especially riparian forests with a mix of measures; intensify conservation agriculture elsewhere to reduce pressure
message: sustainable intensification of smallholder farming can help take pressure off the forest through techniques such as conservation agriculture, especially in combination with agroforestry

Extent of land conversion

Loss of forests and woodlands by conversion, and wild fires caused often by forest clearance, threatens the long-term provision of ecosystem services and functions related to water regulation and biodiversity in the Okavango Basin. Satellite image analysis illustrates that the conversion of forests and woodlands to areas used for small-scale agriculture was clearly the dominant land use change. Continuous agricultural expansion was detected, rising from an annual rate of 5,275 hectares of forest cleared between 1989 and 1993, then up to 12,033 hectares between 2009 and 2013 (Figure 3.9). This implies an increase in the annual deforestation by a factor of 2.3 within 20 years. Overall, about 258,000 hectares of forested areas were cleared for agriculture between 1989 and 2013 which is the equivalent of 5.6 % of the forests in the Okavango Basin.

Analysis of the satellite images (Figure 3.10) confirmed that roads and settlements are major drivers and facilitators of change. Deforestation and conversion to agricultural fields is mainly taking place along the roads and also in concentric circles around the cities. This is due to better access to markets and settlements – and plans of the government to move people from the countryside close to towns and major roads after the termination of the civil war in Angola (Brinkmann 2003, Schneibel et al. 2013).

Effects of deforestation for CC-mitigation:

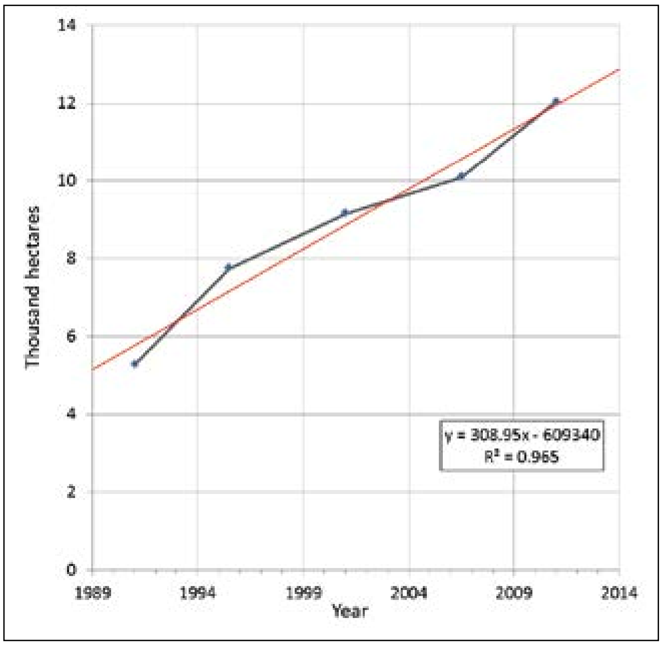
Soils under natural woodlands are balanced at a particular level of carbon input from dead plant material – leaf litter etc. – and root exudates on the one hand, and decomposition by microbes on the other. This equilibrium is disturbed when woodland is cut and both wood and other vegetation removed in order to clear fields for agriculture, because carbon input is very significantly reduced and the existing soil carbon pool is quickly diminished. The conversion of woodlands into farmland releases the greatest quantities of carbon (Box 3.1) compared to conversion into other land uses. This can be explained by the very low input of new organic matter into the soil. This is particularly true when land is cleared by burning, and furthermore crop residues are also burned as part of traditional subsistence agriculture.

Box 3.1: Carbon release through deforestation of woodlands in the Okavango Basin

The conversion of woodland to cropland for conventional smallholder agriculture leads to a carbon release of 50 – 63 t ha-1 in the Miombo woodlands and 10 – 24 t ha-1 in the dry woodlands of northern Namibia and Botswana assuming that the above-ground woody biomass is burned, as it usually is (Pröpper et al. 2015).

To mitigate GHG emissions and favour carbon sequestration, woodland conversion into cropland can be avoided by intensifying agriculture on existing small fields using sustainable land management practices described in Chapter 1, for example by no-till/ minimum tillage conservation agriculture, and associated techniques of adding carbon inputs in the form of manure, and (carbon-rich) crop residues used as mulch to improve soil fertility, suppress weeds and keep moisture in the ground (see Technology ‘Conservation agriculture’ page 247).

Figure 3.9: Annual expansion of agriculture due to conversion of forests in the Okavango Basin (black line). Included is the trend line for all points (red line) and the corresponding R^2 (coefficient of determination). (Schneibel et al. 2016).



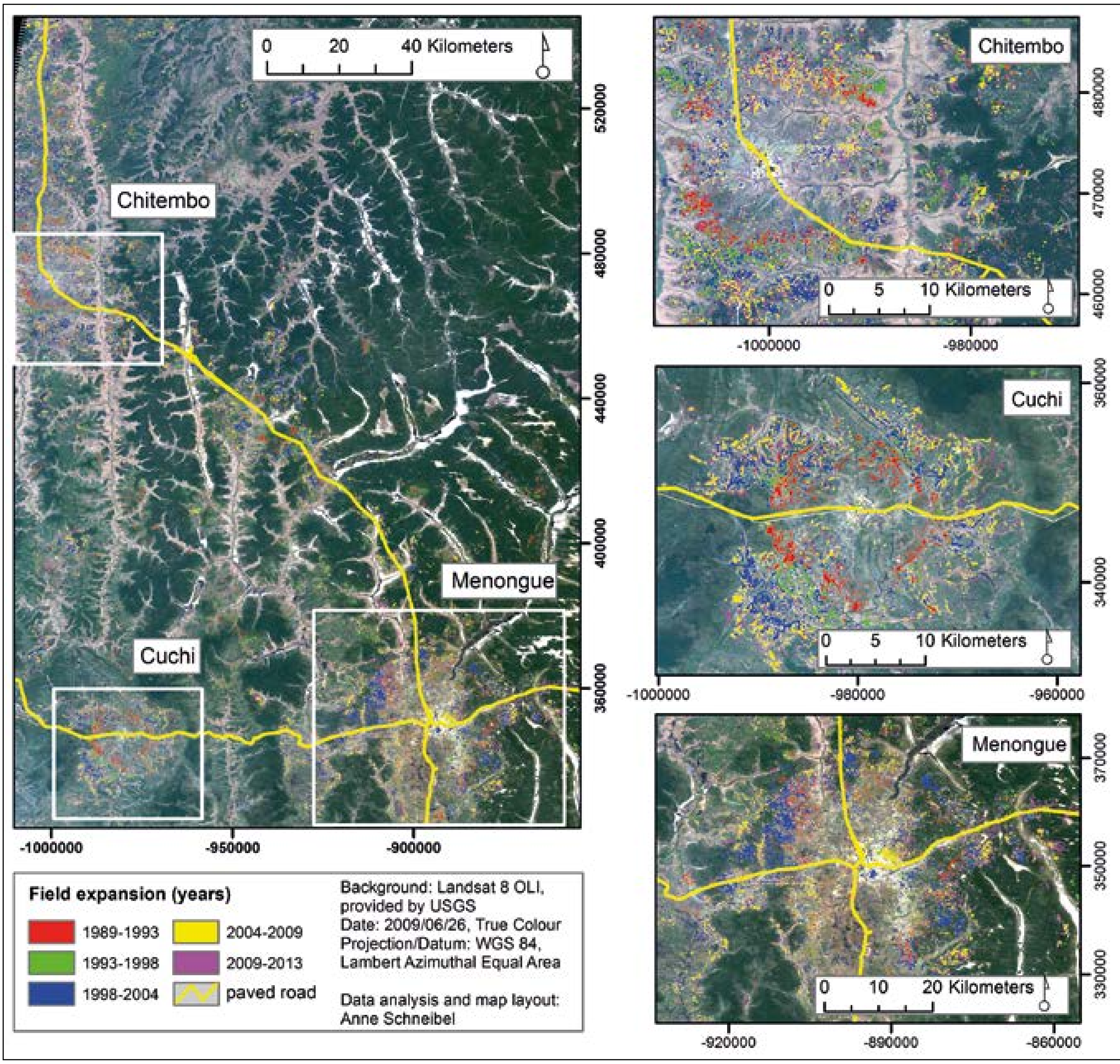


Figure 3.10: Map of field expansion for five time periods between 1989 and 2013 with additional close-ups for the three cities Chitembo, Cuchi and Menongue, in the highlands of Angola. The colours represent different periods of deforestation for the establishment of new agricultural areas (Schneibel et al. 2016).

Synergies with biodiversity and ESS

Protecting woodlands and wetlands within the Okavango Basin not only mitigates climate change but also supports biodiversity and protects ecosystem functions important for water provision – securing both quantity and quality. Avoiding woodland conversion (and woodland degradation) and maintaining a good balance between different land uses such as conservation agriculture on smaller fields (see Technology 'Conservation agriculture' page 247 and Chapter 1 page 30), crop-livestock systems with manure production, timber production and nature conservation, will help protect biodiversity.

Protecting river systems with an intact riparian forest has additional benefits over and above maintaining carbon stocks. These include buffering river flows and floods, protecting rivers from nutrient and sediment pollution, and biodiversity enhancement (Vushe, 2014, see Chapter 2 page 55).

Figure 3.11: Extensive grassland production in Germany with a high variety of species. (Norbert Röder)

Figure 3.12: Hay production from extensive grassland in Germany. (Norbert Röder)

Inner-urban development to reduce land conversion in Germany

Compact settlements and re-greening of cities to 'make them cool' and reduce further expansion of settlements (Germany)

context: reduction of greenhouse gas emissions occurring through land conversion from forests, grasslands and agricultural land to new settlement and transportation areas

problem: heat waves in settlement and transportation areas cause extreme temperatures in cities with sealed surfaces and little greenery leading to health problems and reduced quality of life

solution: reuse of vacant lots, the use of gaps between buildings or the improvement of existing structures (e.g. additional floors) to spare land from conversion; 'fresh air corridors' and improvement of green areas in the city/ unsealing of sealed surfaces for cooling effects, improve existing land use in cities with green infrastructure/ combining houses with trees, CC mitigation and adaptation achieved

message: to adapt to climate change and improve city life, make cities greener and more space-efficient to reduce pressure on adjacent farm and forest land; these measures can have also an indirect impact on reducing GHG emissions

Inner urban development, in this context, means reuse of vacant lots, the use of gaps between buildings and the improvement of existing structure (e.g. additional floors) (see Technology 'Inner urban development' page 199). This 'compact settlement development' encourages efficient use of technical and social infrastructure and thus indirectly contributes to the reduction of GHG emissions by reducing the pressure on forests, grazing and agricultural land. If the focus is on compact settlement development, farm and forest land can be spared from conversion.

There are limits to intensification in cities. The increase of extreme weather events like heavy rain or very hot days (temperatures in excess of 30 °C) are forecast in Germany. Infrastructure damage caused by intense rains or floods, and extra costs incurred by air conditioning or even health-care will become more and more challenging. Thus a mitigation strategy has to be combined with climate change adaptation measures to ensure 'sustainable intensification' of urban land use.

Inner-urban development in Germany by creating 'green and blue climate corridors' (urban green spaces; small lakes and rivers), can help to cope with climate change impacts. High urban densities lead to an increase in the heat island effect (up to 4-6 °C difference) (Zhou et al. 2013) and to increased rainfall runoff. A heat island effect of 5°C may not sound much, but on top of a temperature above 30 °C the increase can be substantial for human wellbeing and health. Therefore, the revitalization of ex-industrial 'brownfields' must go alongside the transformation of impervious surfaces into pervious ones, and with the planning of corridors for air exchange. Compacting settlements in some parts – but leaving green and blue areas in others reduces the expansion of settlements and prevents further overheating. Such measures can make life in the city more resilient to climate change, more attractive – and 'cool'.

Grassland preservation and extensive use in Germany

Preventing grassland conversion through EU incentives, biodiversity and carbon benefits in Germany

context: widespread phenomenon of grassland conversion to cropland in EU countries

problem: grassland conversion to cropland increases GHG emissions and reduces biodiversity

solution: prevent conversion of grasslands and promote sustainable extensive use
- keep and increase carbon stock
- synergy with biodiversity under extensive use, as well as water quality (less agro-chemical use but lower production (economic trade-off)
- the main argument against conversion to cropland for biofuels is the very negative GHG balance
- focus on prevention because of the very long period before GHGs lost can be brought back into the soil and vegetation after conversion

message: where there is pressure to convert grassland remember that prevention is preferable – for climate change and other reasons

Converting grassland to cropland causes high carbon losses during the first years; the opposite, reconversion to grassland, requires decades before sequestration of soil organic carbon to previous levels can be achieved. Thus preventing conversion is the priority (see Technology 'Grassland preservation' page 207). However, increasing demand for cropland and related higher incomes is rendering the preservation of grassland, particularly when it is extensively managed, more and more difficult. But regulations are in place to prevent conversion: a recently adopted EU regulation declares any fallow land as 'grassland under protection' if it has not been cropped for 5 years. The consequence is that farmers bring fallows back into cultivation before that 5 year limit.

Figure 3.13: Experimental field for steppe restoration showing the fence for cattle exclusion under trial in the Kulunda steppe, Russia. (Tatjana Galcova)

Figure 3.14: *Medicago lupulina*, a legume commonly known as hop clover, under test to enrich the Kulunda steppe, Russia. (Tatjana Galcova)

Converting grassland to arable also means loss of biodiversity: grassland is better at maintaining habitats than cropland. Grasslands are usually less intensively managed than croplands and reduced use of fertilizers and pesticides is beneficial for water quality and biodiversity. An incentive for extensive use of grasslands would be to subsidize suitable grazing management. Compared to the widespread indoor housing of animals, extensive grassland grazing may be less profitable but has multiple positive effects on biodiversity, CC-mitigation – and meat quality (Figures 3.11 and 3.12).

3.3 Reversing land conversion

Once converted to intensively used land with lower carbon stocks, it takes time to re-establish the original C-stock when land use once again is extensified. The original conversion, from grassland to arable land, is typically motivated by the drive to intensify the use of land and improve its productivity. Reversing means losing that productivity. Thus it needs special circumstances to induce farmers to re-convert to pasture – such as arable systems becoming unprofitable (either declining prices, or diminishing fertility, or both). While it is rarely the primary goal of farmers, this re-conversion provides benefits in terms of climate change adaptation and mitigation, and of biodiversity conservation.

Grassland restoration in the Siberian Kulunda steppe

Restoring the Kulunda steppe – the value of biodiversity and improved grassland management

context: meadow steppe restoration

problem: natural steppe was converted into high production area -> loss of biodiversity and C-stocks

solution: restoration of steppe by increasing the abundance of native steppe species. Window of opportunity because of former abandonment of agricultural land which is not re-cultivated
– support/ speed-up restoration practices
– re-establishment of key species
– stop overgrazing/ exclude cattle
Steppe takes several years to regenerate

message: restoration of grasslands – where economically and socially acceptable – can bring boosts in terms of carbon sequestration and biodiversity

In the course of the Soviet 'Virgin Lands Campaign' (1954-1963), the vast majority of the Kulunda steppe was converted into intensive cropland. The remaining areas of natural steppe became increasingly fragmented, which in consequence rendered many native steppe species scarce and red-listed (Aleksandrova et al. 2006). After the collapse of the Soviet Union this trend was reversed and abandonment of agriculture significantly decreased the extent of arable land in Central Asia (Kraemer et al. 2015). This provided the opportunity to increase the abundance of native steppe species with the help of restoration measures. Experience from prairie restoration of similar areas in North America indicates that the re-colonization of different key species may require specific treatments to ensure success. In addition, overgrazing must be restricted to support the regeneration of vegetation.

Preliminary results of experiments revealed that cattle exclusion can considerably facilitate meadow steppe restoration (Elesova et al. unpublished data; Figure 3.13). However, their results also imply that only a few years of exclusion is insufficient for the regeneration of very degraded sites. Field experiments in Kulunda steppe restoration showed that isolation contributes to improve restoration, plant coverage and stocks of above ground biomass. However, as already noted, re-accumulation of carbon stocks is much slower than the equivalent losses when grassland is converted to cropland.

Tests with re-establishment of species have determined that the best timing for sowing seeds in the dry steppe under a strip-till method (only narrow strips are tilled in the grassland) is during the 2nd and 3rd weeks of October. Several steppes species were tested for reseeding, including legumes such as *Lotus corniculatus* and *Medicago lupulina* (Figure 3.14).

3.4 Restoring wetlands and organic soils

Wetlands in the coastal zone in northern Germany

Reduced disaster risks by extensification and adaption to climate change

context: low lying coastal landscapes with extensive reed stands were drained for cultivation

problem: Cultivated land below sea level requires drainage and pumping -> expected increased problems under climate change/ predicted sea level rise; floods will cause methane emissions; intensification of land use decreases biodiversity and at the same time increases GHG emissions

solution:
- water retention areas (polders) and adapted/ diversified and extensive land use allow for both biodiversity increase (fauna) and carbon storage, also better climate change resilience → re-naturalization/ extensification of unprofitable areas due to effect of climate change, land use change, changing land from C-source to C-sink
- ECO DRR (disaster risk reduction using natural systems)/ management change; space for biodiversity
- special situation in the Baltic sea: realignment of sea walls (dykes) and opening areas to the seawater again. Sediment deposition reacts with methane and mitigates emissions

message: In coastal landscapes below sea level, climate change induced sea level rise can make land unprofitable due to increased drainage: thus the need to seek alternative remedies

Low lying lands (up to two meters below sea level) along the German North Sea coast need to be drained to be farmable. This land was converted from natural wetlands (salt marshes and bogs) to grasslands and croplands: the process of 'impoldering' means land is embanked by dykes to protect it against the sea and then drained. With climate change, higher precipitation and more extreme events are expected to become more frequent. Also sea level rise is predicted. A dense drainage network prevents inland flooding today. But an increased risk of flooding is expected, as the capacity of the drainage network is limited. Temporary flooding of intensively used agricultural land will lead to reduced production and high methane emissions, and therefore to a negative effect on climate change. A possibility to prevent flooding is the development of 'water retention areas' (see Technology 'Polders to improve water management' page 215, Video and Chapter 2 page 70).

In general, water retention areas will be located in the low elevated parts of the landscape, to enable flow of water towards them. Only a small embankment will be necessary to secure the surrounding land against flooding. The current land use within these areas will shift from dairy farming and arable land to extensive grassland use and open waters covered with (harvestable) reed stands (see Technology 'Polders without agriculture' page 219 and Video).

Along the Baltic coast of Germany a practice for GHG mitigation is the so-called 'realignment'. Seawalls are shifted landwards, and formerly protected land is exposed to seawater again. However this will change the amounts of GHG emitted (source) as well as carbon stored (sink) – dependent on various parameters. The main factors determining these levels are water levels and soil types.

Land under agriculture has limited capacity as a carbon sink, whereas wetlands have a high capacity for carbon sequestration in the soil. The less intensive the land use is, the more organic material is available for carbon sequestration. Thus the wet conditions in water retention areas and in de-embanked coastal areas can increase the carbon sequestration rates within the landscape. Reduction in intensity of land use or abandonment of intensive agricultural land will lead to more plant material available for permanent storage of this organic carbon in soils. Within water retention areas with high groundwater levels (to cope with predicted sea level rise and extreme events), the high water levels will increase carbon sequestration rates. The highest increase in carbon sequestration will take place on wet, abandoned sites.

The amount of sequestered carbon depends on water levels and the soils. Organic soils are at risk of emitting huge amounts of CO_2 when drained. Under wet conditions, these soils are able to sequester carbon, thus the water level should be kept near to the soil surface. By optimising water levels, the landscape is best able to accumulate organic matter (through peat formation) and therefore sequester carbon.

Calculations of GHG emissions under different land use, sea levels, and climate change scenarios was done using modelling techniques (COMTESS 2016). The results show that natural growth of reeds and peat accumulation will take place in water retention areas and on sites with managed realignment, sequestering and storing up to 15 t CO_2-equivalent per hectare each year in organic soil layers. In contrast, under typical water levels of intensively used grasslands (water level 75cm below soil surface) on organic soils, a net emission of approximately 30 t CO_2-equivalent per hectare and year will occur (see Figure 3.4 on Global Warming Potential page 79).

For different scenarios, where climate change impacts were accounted for, the sums of CO_2 sequestration were modelled. This allowed comparisons between land use as well as projections into the future. The increase from 2050 onwards is due to sea level rise, which increases wetter areas (Figure 3.15).

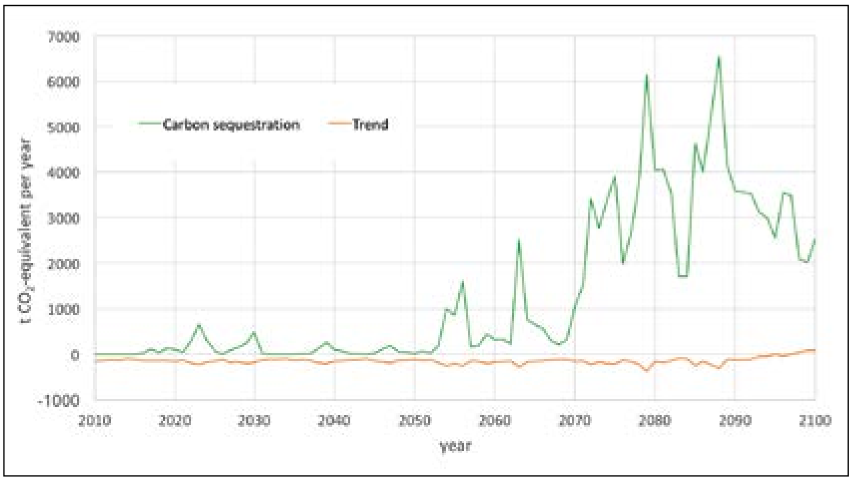


Figure 3.15: Annual regional sums of climate change mitigation (sum of CO_2 sequestration minus greenhouse gas emissions) given in CO_2 equivalents per year under optimized carbon sequestration conditions (green line) and under business as usual (brown line), Michaelsdorf (Baltic Sea, Germany). The underlying model includes sea level rise and extreme weather events with wet and dry years. In wet years more carbon is sequestered, in dry years less. (COMTESS 2016)

Figure 3.16: High water levels with reeds leading to increased methane emissions at the German North Sea coast. (Martin Maier)

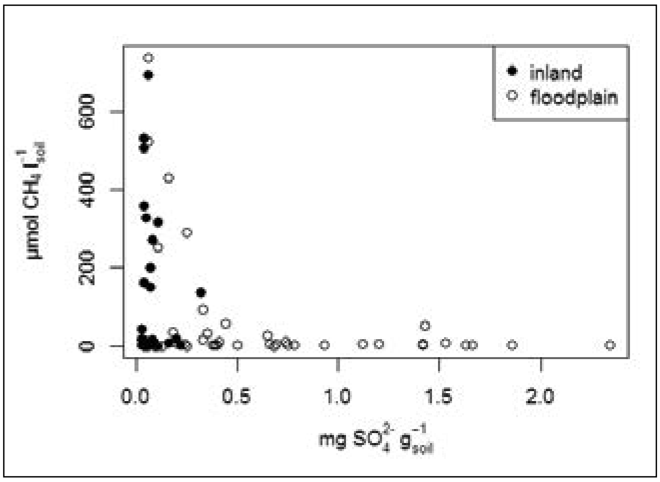
Figure 3.17: Managed realignment at the Karrendorfer Wiesen (Baltic Sea, Germany). (Jasmin Mantilla-Contreras)

As noted, high water levels can lead to high emissions of methane (Figure 3.16). These emissions may significantly increase by re-wetting land. Therefore, there is a 'golden' balance to be found in land use and water level management to enable carbon sequestration without this being offset by increased methane emissions.

On mineral soils, emissions of CO_2 are low, even with low groundwater levels and intensive land use. This is due to the low amount of organic carbon in the soils. Yet on mineral soils too, methane emissions are significant when water levels are high or fluctuating. Thus the water level must be managed here, too. On organic soils, there is a trade-off between C-sequestration at high water levels and high methane emissions (see Figure 3.4 on Global Warming Potential page 79).

In the 'realigned areas' on the Baltic coast a different dynamic is taking place. Opening land to seawater leads to deposition of marine sediments in the water retention areas (Figure 3.17). The sulphate in the marine sediments reacts with the methane in the soil. This chemical reaction transforms the methane into CO_2 (Figure 3.18). Because methane is a much more active GHG than CO_2 in terms of global warming potential (though it has a shorter life in the atmosphere) this practice effectively reduces the overall GHG emissions and has a high climate mitigation potential. The potential to combine benefits from climate change mitigation with biodiversity in the coastal region of the North and the Baltic Sea is further explored in Chapter 4.

Figure 3.18: Sulphate ($SO^{2-}{}_4$) and methane (CH_4) concentrations in inland and tidal marshes (floodplain) in the North Sea coast, Germany measured at soil depths ranging from 20 to 150 cm. The low methane emissions are clear when sulphate is present in the soil. The sulphate originates from marine sediments on the tidal marshes (Witte and Giani 2016).



3.5 Reducing emissions from agricultural practices

All soil conserving practices have the co-benefit of CC-M because of their protection of the topsoil in which high percentages of soil organic carbon (SOC) are stored. The purpose of those practices is primarily to prevent land degradation such as erosion, and to increase soil organic matter to improve production as described in Chapter 1.

Examples presented below focus on aspect of climate change mitigation by:

- Land management practices that have been specifically re-designed to mitigate GHG emissions because of high emissions under the current practice. These include coping with water scarcity in Vietnam to adapt to climate change.
- Land management practices that have been re-designed for sustainable intensification of production and have synergies with carbon sequestration in the Kulunda and Tyumen steppe of Russia (no-till management) and in the drylands of Brazil (grazing management).

Reducing methane in rice production in Vietnam

Reducing methane emissions by alternative wetting and drying in lowland rice cultivation of Vietnam

context: fast-growing populations demand higher rice supplies under increasingly difficult production conditions of declining water availability and water quality

problem: methane emissions in paddy rice production. Irrigated rice production will always produce methane. At the same time water availability is getting lower under climate change

solution: alternating wet and dry cultivation → saving water, reducing methane emissions → no trade-offs with NO_2 emissions and yields

message: altering cultivation practices – in this case by manipulation of irrigation periods – can have a significant impact on GHG emissions

Rice production in Asia is facing tremendous challenges in the 21st century. Fast-growing populations require higher rice supplies under increasingly difficult production conditions. Among these are declining water availability and quality (Tuong and Boumann 2001, 2003). Rice production under ponded water, however, releases high amounts of methane (CH_4), which has a global warming potential (GWP) 25 times higher than carbon dioxide (IPCC 2007). The CH_4 emissions from rice fields in Vietnam are currently estimated at 6.3 teragram per year (Tg yr-1) (Minh et al. 2015) corresponding to 50.5% of agricultural GHGs and 18.1% of

Figure 3.19: Paddy fields under 'Alternative Wetting and Drying' in Vietnam. (Andreas Havemann)

Figure 3.20: Greenhouse gas sampling in the field at Nam Phuoc, Vietnam. (Tran Dang Hoa)

all GHG emissions in Vietnam (MONRE, 2014). Hence, there is a conflict between irrigation and GHG emissions in rice production.

Traditional continuous rice flooding (CF) and alternate wetting and drying (AWD) irrigation technologies were compared in Quang Nam province, Central Vietnam, with respect to GHG emissions and potential yield trade-offs. The alternative wetting and drying (AWD) technology is a water-saving and methane mitigation technology that lowland (paddy) rice farmers can employ, primarily to reduce their irrigation requirement. Rice fields under this technology are, as its name suggests, alternately flooded and dried (Figure 3.19). Results from experiments proved that AWD is a potent GHG mitigation option for irrigated rice in Vietnam showing a reduction in CH_4 emissions of 29% on average compared to continuous flooding, as well as providing a higher grain yield of 4% on average over all sites and seasons (Figure 3.20).

Increasing carbon stocks with no-till and minimum tillage in the Kulunda steppe Russia

No-till and minimum tillage to prevent the next dust bowl in the Kulunda steppe

context: in the driest areas of the Kulunda steppe, the beginning of desertification has already been observed. This also affects areas of intensive crop production: a 'dust bowl' needs to be averted

problem: desertification by wind erosion, salinization and carbon loss → negative effects on production

solution: no/ min-till: soils become a carbon dioxide sink rather than a source, using sustainable land use policies and practices that will allow for the stabilisation of agricultural production and simultaneous CC mitigation

message: new cultivation practices based on reduced tillage can yield multiple co-benefits of production, soil conservation and reduction of GHG emissions

In the driest areas of the Kulunda steppe, the beginning of desertification (i.e. land degradation by wind erosion and salinization) has already been observed. There is an urgent need to develop sustainable land use policies and practices that will allow for the stabilisation of agricultural production and the simultaneous sequestration of carbon. An important soil management challenge is that soils should become a carbon dioxide sink rather than a source, thereby conferring the region a positive role in respect to world-wide concerns about mitigating climate change.

Cropland in the Kulunda steppe can provide large-scale mitigation potential against greenhouse gas emissions over a long time period. The agronomic and economic aim for the Kulunda steppe is to implement farming practices that can harvest carbon dioxide from the atmosphere (through photosynthesis) and store it in the soil, based on no-till and minimum-tillage methods (see Technology 'Minimum tillage' page 251). Research has shown that there is a significant relationship between soil organic carbon (SOC) and aggregate stability in the soil. Cropland has lower SOC content and aggregate stability than natural (extensively or unused) soils. Hence, with increasing aggregate stability, SOC could be sequestrated and wind erosion would decrease (see Chapter 1 page 20).

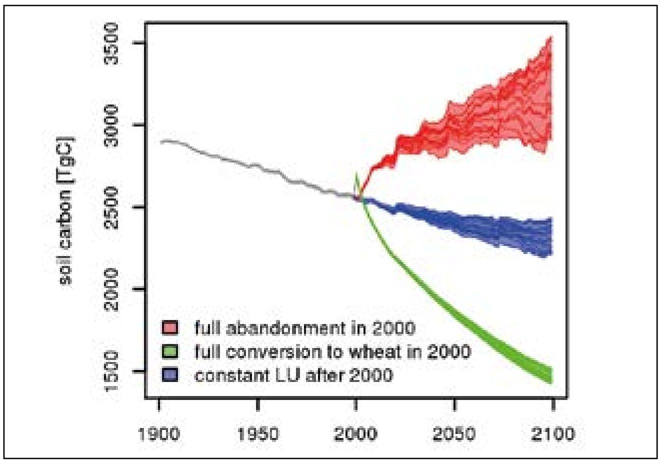
Therefore, a carbon cycle model was used to investigate into soil carbon changes under three scenarios (LPJmL Dynamic Global Vegetation Model - Bondeau et al. 2007, Schaphoff et al. 2013):

Static land-use patterns, i.e. no change in current land-use: Leads to a total soil carbon loss in the Kulunda steppe over the 21st century of between 140 and 340 TgC, depending on the climate scenario and resulting emissions.

Assuming complete agricultural abandonment over the entire region: The climate-induced loss of soil carbon is more than made up for by a re-establishment of natural steppe and woody vegetation and a corresponding net increase in soil carbon of 360 to 970 TgC over the 21st century.

A complete conversion of all land to cropland (wheat): The climate-induced carbon loss is accompanied by additional soil carbon loss from land-use change, leading to overall carbon losses of 1050 to 1130 TgC over the 21st century (Figure 3.21)

Figure 3.21: Changes in soil carbon stocks under three land-use change scenarios, and future high emission climate change (SRES A2 scenario) in the Kulunda steppe. TgC: teragram carbon, LU: land use. (Nakicenovic and Swart 2000)



Conclusions

Land use change, land and water management, as well as climatic conditions determine how much carbon can be sequestered or is emitted in the form of greenhouse gases. Related to climate change mitigation, the biggest challenge is how to turn the land from a C-source into a C-sink.

Land use itself is a factor determining GHG losses, and the process of land use change is often a GHG source in itself. Major carbon and GHG emissions occur when:

- **land use is intensified resulting in:**
  - soil disturbance, reduced aggregate stability and loss of soil organic carbon (leading to loss of soil fertility)
  - loss of vegetation and soil cover (bare soils)
- **land use is changed through:**
  - conversion to a land use with lower C-storage potential e.g. forests to grasslands and cropland to settlement and transportation infrastructure
- **wetlands are drained and converted to grass and or cropland**

If land management is to contribute to mitigation of climate change, the carbon storage potentials of soils and vegetation have to be taken into account. This implies that the impacts of different land uses and groundwater management on carbon sequestration rate and total storage capacity should be known.

A first strategy is to reduce emissions from land management changes and intensive cultivation which constitute a C-source

- spare land with a higher C-storage potential from conversion, through sustainable intensification of land already in production (mainly cropland)
- avoid or reduce major land use change (e. g. deforestation, fast urbanization/ erratic urban sprawl)
- protect wetlands and grassland from conversion
- improve production systems that currently release high GHG: e.g. reducing GHG emissions by drying and wetting of paddy (low land) rice fields.

A second strategy is to protect existing C-sinks in soils with high carbon stock from 'burning up' carbon/ organic matter through oxidation

- avoid excessive drainage, consequent oxidation (decomposition) and subsequent mineralization of organic soils, keep groundwater levels at an optimal height (by regulating groundwater levels, protect, re-establish or restore wetlands)
- avoid agronomic practices and production systems that accelerate soil erosion, SOM decomposition and oxidation: replace with no-till/ minimum tillage, permanent soil cover, grazing land management etc
- avoid clearance of bush/ forest associated with burning, overgrazing and overexploitation of vegetation, reducing above and below ground organic matter.

A third strategy is to increase C sequestration and improve C-storage capacity

- re-convert intensively used land to extensive systems, e.g. rewetting of organic soils, protection, extensification of intensively used cropland or grazing land; or reverse the original process of land conversion itself (e.g. back from cropland to grasslands restoration; recreation of wetlands) (from source to sink)
- increase C-sequestration and storage/ stocks of mineral soils. Apply practices/ agronomic management that improve above and below ground biomass production

Improved management of mineral soils through better cover and less soil disturbance can improve carbon stocks without having to increase groundwater levels. Yet, with high water levels, carbon stocks can even be further increased but there is a risk of emissions of methane in both organic and mineral soils.

Some strategies for CC-mitigation including re-wetting of organic soils and extensification of grassland have clear co-benefits with both biodiversity preservation and increasing the resilience of the whole system, including CC-adaptation potential.

Climate change mitigation through improved land use and management is often a compromise, especially due to the time period required and slow benefits accruing to the local land users. CC-mitigation is a long term investment with a long-term focus to achieve its goal and get some benefits. Those who invest in improved land management do not get immediate and direct benefits from their improved land. Yet, they make a contribution to society at large.

CHAPTER 4

Protecting biodiversity and ecosystems


Western Siberia, Wanja Mathar

Introduction

Biodiversity provides important ecosystem services (ESS) for human needs, of which agricultural production and provisioning of water are key for food security. But current land use and land use changes often severely reduce biodiversity and ecosystem function (Schulz et al. 2016; Hansen et al. 2001). A main driver of biodiversity loss and degradation of ecosystems is conversion of natural and semi-natural land use systems into agricultural land, settlements and transportation systems. Natural forest, steppe, wetlands and grasslands are lost – further adding to the ongoing biodiversity crisis. A second threat to biodiversity is intensification of cropland and grazing land. This process threatens agrobiodiversity (crops diversity as well as wild species diversity on agricultural lands) and simultaneously leads to degradation of these agro-ecosystems. A third driver of biodiversity loss is overuse of natural and semi-natural land by, for example, non-sustainable collection of natural products and overgrazing. In some areas, it is a combination of population growth and poverty that lead to over-exploitation and deterioration of natural resources and agro-ecosystems. Conversion back to grasslands (or other systems) or extensification of currently intensively used agricultural systems with low biodiversity can lead to recovery and improvement. On the other hand, in some areas, abandonment of existing agricultural systems with a high level of biodiversity can lead to a decrease of biodiversity. Thus, it is imperative to analyse the local or regional context in order to identify suitable solutions for biodiversity protection.

In previous chapters the following aspects also related to biodiversity protection, regeneration and improvements are covered:

- Chapter 1: crop rotations, intercropping and flower strips instead of monoculture, integrated/ biological pest control
- Chapter 2: protection of riparian forests, eco-based disaster risk reduction (DRR): where natural systems are included for the protection against disasters
- Chapter 3: land management related to climate change mitigation and enhancing recovery of the carbon stocks, in the soils, as well as above-ground.

These land management practices often go hand-in-hand with supporting or enhancing biodiversity. In this chapter the focus is on biodiversity as the primary goal. Several examples of biodiversity conservation and sustainable use of natural and semi-natural systems are presented. They address in particular:

- Management of protected areas
- Payment for ecosystem services

Figure 4.1: National Road 14D of the Asian Highway connecting Laos with Vietnam and splitting the Song Thanh Protected Area, the largest in Vu Ghia Thu Bon (VGTB) River Basin, into two parts. (Ho Dac Thai Hoang)

4.1 Managing protected areas

Protected areas are defined as a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values (Dudley, 2008). Three examples of managing protected areas are presented below:

- Protected area concept in Vietnam
- Enforcing protected areas in the São Francisco River Basin in Brazil
- Protection within a much used agricultural area and creation of green / conservation corridors in Mahafaly Plateau in Madagascar

Protected area concept in Vietnam

Biodiversity research for designing protected areas

context: as soon as roads are constructed, access to the last unspoiled forest areas is opened; often, roads are initially used for legal selective logging, but are subsequently used for illegal logging

problem: deforestation through conversion, over-exploitation and plantation of exotic trees

solution: install protected areas/ protect biodiverse forests, reforestation with economically useful native trees; awareness-raising through research on biodiversity and the value/ benefits of biodiversity conservation; developing priorities and recommendations for decision-makers and stakeholders; 'conservation concept' and mapping overall protected area network

message: biodiversity conservation in VGTB needs to go hand in hand with environmental education and provision of alternative ways of income generation to halt illegal logging in the long run

Vietnam is one of the few countries in the world with steadily increasing forest coverage – though much of this extra 'forest' comprises plantations. However, the area of native forest in Vu Gia Thu Bon (VGTB) watershed in Central Vietnam is steadily decreasing and the once continuous forests are fragmented by:

- conversion of forest to agricultural lands, plantations, infrastructure and settlement areas;
- deforestation and degradation through exploitation for timber;
- harvesting of wild plants and animals at unsustainable levels;
- introduction of exotic (non-native) tree species.

Although located in internationally recognised ecological priority areas adjacent to the Annamite Mountain Range – which are known for their high levels of biodiversity (Box 4.1), there is surprisingly little known about forest diversity and the patterns of tree species distribution. This is primarily due to difficult access to the remote mountain areas. As soon as roads are constructed, access to the last unspoiled forest areas is opened; often, roads are used for legal selective logging, but are subsequently used for illegal logging (Figure 4.1).

The distribution patterns of native tree species in VGTB River Basin were assessed to identify priority areas for conservation, and thus for ESS maintenance, and to develop recommendations for adequate forest management strategies.

In VGTB River Basin, an area of roughly 12.000 km^2, it proved difficult to find areas of 1 km^2 of continuous near–natural forest needed for an assessment of native tree species. This was due to extensive plantations of mainly (exotic, non-native) *Eucalyptus* and *Acacia species*. In three field campaigns, 187 tree species were identified in 16 plots of 1 km^2 in the midlands and highlands of the VGTB basin. Fieldwork, combined with tree species distribution modelling (MaxEnt), showed that the highest levels of potential tree species richness lay in the highlands in the south of the VGTB Basin, and in the west on the border with Laos. The midlands demonstrated lower levels of potential tree species distribution, with only few remnants of near-natural forests in remote valleys and on steep mountain slopes. Through an overlay of modelled tree species richness with the existing road network, less fragmented priority areas with high richness were identified for conservation (Figure 4.2).

Box 4.1: Forests in Vietnam are highly diverse - but threatened
Seriously scarred in the years of the Vietnam War between 1965 and 1975, the overall forest area has grown steadily since the early 1990s from approximately 25% of the country's area in 1992 to more than 38% in 2005 (Meyfroidt and Lambin, 2008). According to the Vietnam Development Report 2011 based on an overview by the World Bank from 2005, Vietnam hosts 310 mammal species, 840 bird species, 286 reptile species, 162 amphibian species, 3,170 fish species and 14,000 plant species.

The research on biodiversity came up with following recommendations for decision-makers and stakeholders in VGTB River Basin:

- Centres of elevated modelled tree species richness found are recommended as priority areas for the creation of a biodiversity corridor in the VGTB basin.
- In order to close the gap identified, a new protected area ('core priority area') should be established in its north-western area and be connected to existing protected areas to create North-East and East-West corridors.
- Plantations of native tree species, ideally with high economic and ecological value, should be introduced - as native tree species need less fertilizer and attention, thus allowing a more biodiverse understorey.
- Awareness-building measures for the need of biodiversity conservation in general, as well as for the use of endemic tree species for income generation have to be carried out to sensitise local communities and demonstrate the benefits of nature conservation.

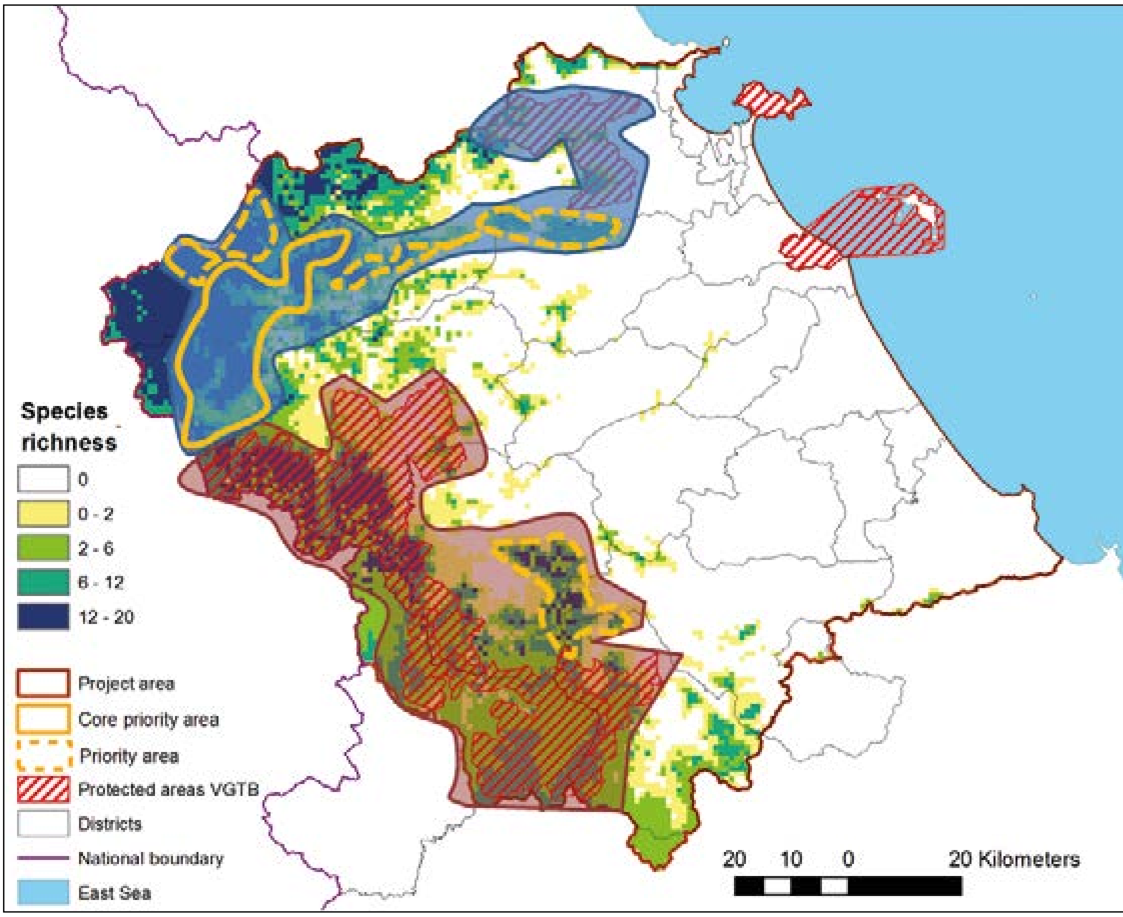


Figure 4.2: Linking priority areas for conservation to establish a biodiversity corridor from the north-south and east-west in the Vu Ghia Thu Bon (VGTB) watershed in Vietnam. Core priority and priority areas for future protection are outlined with an orange line and dotted line. The larger areas highlighted show the two axes of the proposed biodiversity corridor: in light red connecting along the north-south axis; in light blue along the West-East axis linking forest areas from Laos to the sea. (Claudia Raedig)

Knowledge for protection of *Caatinga* woodlands, Brazil

Knowledge-based planning and protection of *Caatinga* woodlands in the São Francisco River Basin, Brazil

context: the natural *Caatinga* woodlands are under high pressure of exploitation and overuse - even under protection. Recovery of forests is detectable in some areas but high biodiversity with a major share of the typical flora and fauna can only scarcely be found

problem: degradation (esp. soil erosion), biodiversity loss and high GHG emissions, growing pressure, inadequate incentives / implementation of regulations (enforcement) to protect *Caatinga* woodland, incomplete knowledge base and lack of monitoring

solution: raise awareness, improve knowledge base, enforce monitoring, enforce implementation of existing regulations, develop an overall protection plan: connected areas, good governance to protect a biodiverse system under pressure

message: natural resource degradation can sometimes be better addressed through education and awareness-raising than legislation alone

The best concept for protected areas is useless if it is not respected by the people living in the area. In the São Francisco River Basin in Brazil the natural *Caatinga* woodlands are under high pressure of exploitation. *Caatinga* means 'white forest'. Small trees, on average smaller than 6 m, which shed their leaves seasonally are common. The understorey is mainly composed of small woody species, including small cacti and bromeliads, and during the rainy season grasses and annual plants. Although parts of the woodlands have been placed under protection, little or no control of these protected areas means that there is continued indiscriminate cutting of *Caatinga* (Figure 4.3). Often, trees of the *Caatinga* are used for timber for construction, charcoal production or firewood, leading to lower forest densities. Some areas are also converted into settlements while other areas are completely cleared for agricultural purposes. The 'command and control system' for the protected areas is practically dysfunctional. Apparently, the costs of enforcement are not outweighed by the expected benefits.

This is leading not only to the loss of a unique and biodiverse ecosystem but has climate change mitigation implications as well. The native *Caatinga* vegetation and its soils are carbon sinks. Conservation of the *Caatinga* forests is crucial for carbon sequestration - and this is recognised, and different governmental regulations are laid down in the Forest Act. For instance, maintaining a buffer zone of native vegetation along water bodies and the conservation of a proportion of each farm for native vegetation are amongst such regulations (Brazil 2012). Nevertheless, other than in the Mato Grosso area in Brazil, they are rarely enforced (see Chapter 2, Section 2.2 page 63).

The consequences of this intensive land use on biodiversity status have been studied in relation to model species richness and identification of priority areas for protection (using MaxEnt software). This exercise revealed the limited knowledge base regarding the *Caatinga* biome. This lack of knowledge has influenced the results of biodiversity modelling, and may be also responsible for the fact that, in the past, the *Caatinga* was not identified as a priority area for nature protection. So far, protection strategies have been focused on regions where there was more research and knowledge about biodiversity.

Figure 4.3: View over sparse *Caatinga* vegetation to the Itaparica reservoir in Itacuruba municipality, Brazil. (Johann Köppel)

Figure 4.4: Diverse *Caatinga* vegetation in the Serra da Canoa conservation area, Brazil. (Marianna Siegmund-Schultze)

Using the research data and modelling, the officially designed protected areas in the São Francisco River Basin have been reassessed in view of the their current land use. About 9% of the protected areas in the studied *Caatinga* woodland were characterised as being currently under intensive human land use. An analysis over time indicated rapid and increasing degradation process in the region around the Itaparica reservoir, despite the fact that overall forest cover has increased in the entire *Caatinga* region over the past decades (Schulz et al. in press).

This endangers the current and potential value of biodiversity and ecosystem functions of the *Caatinga* woodlands, in particular:

- the endemic fauna and flora is adapted to very harsh environmental conditions and thus has potential value as gene pool for plants and animals, as well as being a source of information regarding adaptation to a harsh environment;
- the function of woodland to enhance groundwater recharge; and
- the role of the existing woodlands in protection against desertification and soil erosion (see Chapter 1 page 42)

In the São Francisco River Basin, and more specifically in the neighbourhood of the Itaparica reservoir, an existing conservation area under state recognition (Serra da Canoa, Figure 4.4) is being supported by biodiversity and species lists monitoring. These data on species diversity (which is higher in the conservation area than outside) is needed to justify the conservation of the area and to prioritize its implementation. This supports the need for monitoring, reporting and eventually securing the protection of the area. A higher impact of protection is expected when the value of the *Caatinga* woodlands is recognized at national level. Research has also shown the need to connect existing conservation areas with additional new protected areas to create conservation corridors or "stepping stones" for the exchange and spread of animal and plant species.

In order to sustain biodiversity management of the *Caatinga* woodlands, the underlying knowledge base needs more attention. There is a clear knowledge gap, especially when compared to other biomes, for instance, the Amazon. There is not enough funding for monitoring campaigns. However, the poorly-studied *Caatinga* biome should receive the same governmental recognition as other tropical ecosystems.

Managing protected areas in Madagascar

Research and community-based monitoring and corridors between protected islands, Mahafaly Plateau in Madagascar

context: the unique spiny forest ecosystem of Madagascar with its high degree of endemic plants and animals is threatened by unsustainable land use techniques

problem: deforestation, overuse and disconnected protected areas (no mobility for plants and fauna) and climate change

solution: study habitat requirements for the protection of a biodiversity hotspot and apply a mix of measures

- support long-term monitoring and awareness with para-ecologists and develop cost-effective monitoring (using flagship species)
- overcome fragmentation by leaving / re-installing corridors, especially hedges
- silvicultural measures in the forests to support sustainable use of timber and NTFP
- management of invasive species, monitor risk

message: threats to biodiverse habitats may be best approached by a combination of technical measures – accompanied by training local community members in monitoring

Averting biodiversity loss on the Mahafaly Plateau in Madagascar is challenging. The unique spiny forest ecosystem of Madagascar with its high degree of endemic plants and animals is threatened by unsustainable land use techniques, for example slash and burn, non-sustainable collection of natural products, and overgrazing (see Chapter 1). These practices have led to a high rate of deforestation (Brinkmann et al. 2014) and the loss of biodiversity and forest-related ESS. The conservation of one of the world's biodiversity hotspots is of global relevance.

Within the study region, the protected areas alone are unlikely to be adequate to conserve the endemic species, because even the large protected areas (such as the 220,000 ha Tsimanampetsotse National Park) are probably too small to maintain viable populations of animal and plant species. This is especially so, since biodiversity decline outside protected areas has negative impacts on the protected areas themselves (Laurance et al. 2012). Furthermore, even without direct human disturbance, protected areas are subject to climate change. As a result, habitat suitability is affected. Species survival depends on the possibility of moving to more suitable habitats. However, if protected areas become islands in a heavily used landscape, many plants and animals will not have this possibility.

Figure 4.5: Radiated Tortoise (*Astrochelys radiata*): a flagship species for biodiversity monitoring in Madagascar. (Y.R. Ratovonamana)

Figure 4.6: Staff of Madagascar National Parks during a workshop on monitoring techniques: here, vegetation. (Y. R. Ratovonamana)

Monitoring biodiversity:
In order to conserve the unique biodiversity, there is a need to study and separate direct human impact (e.g. destruction of natural habitats) from long-term climatic changes (e.g. aridification). The development of mitigation strategies to counter loss of biodiversity requires intimate knowledge of habitat requirements of the native plants and animals.

By linking information about the current state of biodiversity in the Mahafaly region to land management, the objectives of the study were to: (1) learn more about plant and animal responses to habitat alterations, (2) find options on how to integrate biodiversity conservation within the landscape outside the protected areas, and (3) provide methods on cost-effective monitoring of biodiversity components.

Baseline data collection and long-term monitoring of flagship species (charismatic species that gain people's attention) in the spiny forest ecosystem are conservation priorities of Madagascar National Parks (MNP). One prominent example of a flagship species is the Radiated Tortoise (*Astrochelys radiata*, Figure 4.5). Its distributional range has been drastically reduced within the last decades due to illegal poaching. It is listed as 'Critically Endangered' on the IUCN Red List (IUCN 2015). The Radiated Tortoise is used as an important food for some of the local human population and provides cash income when sold on the regional and international market. Further flagship species were monitored, such as the tortoise (Hammer and Ramilijaona 2009), the carnivore *Galidictis grandidieri* (Marquard et al. 2011) and the lemur *Microcebus griseorufus*. Research efforts are continuing to support the establishment of long-term monitoring programmes in close collaboration with governmental and non-governmental organizations (e.g. World Wildlife Fund) and include people from villages surrounding the park.

Long-term monitoring of the environment and biodiversity is a core duty of the Madagascar National Park (MNP), the national authority for protected area management in Madagascar. However, standardized and regular monitoring is hampered by poor data availability and quality, and a lack of sufficient staff for monitoring. The lack of staff was compensated for by deliberate integration of local people into the monitoring process. Community-based monitoring and training and involvement of 'eco-guards' or 'para-ecologists' in monitoring techniques (agriculture and landscape ecology) and interview methods provided a promising way forward to greater and more meaningful involvement of the community in monitoring and conservation (Figure 4.6).

Developing/ protecting biodiversity corridors in the landscape:
The populations of most plants and animals in the Mahafaly region of south-western Madagascar suffer from deforestation and forest fragmentation. Options on how to integrate biodiversity conservation within the landscape - outside the protected areas - by developing a concept for a conservation network seemed the most plausible. Reptiles as surrogate taxa (surrogate taxa are used widely to represent attributes of other taxa) were used to assess impacts of human land use on ecosystems. Apart from birds, reptiles are the dominant vertebrate group in the study region, integrated in nutrient cycles both as predators and prey. They can play integral roles in ecosystem service provisioning such as pest control. Changes in their diversity are likely to cascade through the ecosystem.

The effects of habitat alterations on reptile species richness and occurrence were examined (Figure 4.7). The overall species richness was negatively affected by human-induced land cover changes, reflecting a reduction in forest and vegetation cover. This relationship is non-linear, and there is a threshold of woody vegetation cover at about 10-30% remaining vegetation in the landscape, after which reptile species richness decreased markedly (Nopper et al 2015).

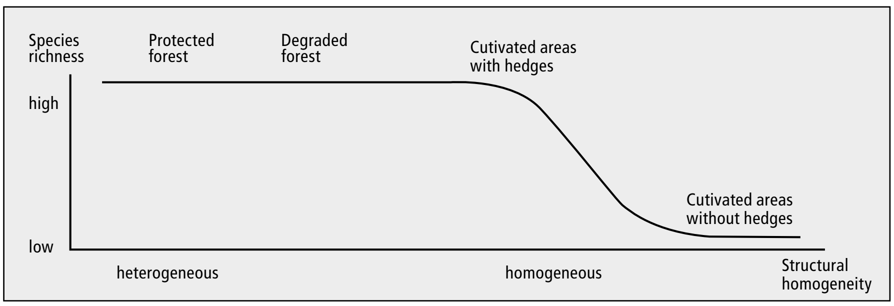


Figure 4.7: Schematic display of the relationship between reptile species richness and the structural heterogeneity of the landscape, Madagascar. (Nopper et al. 2015).

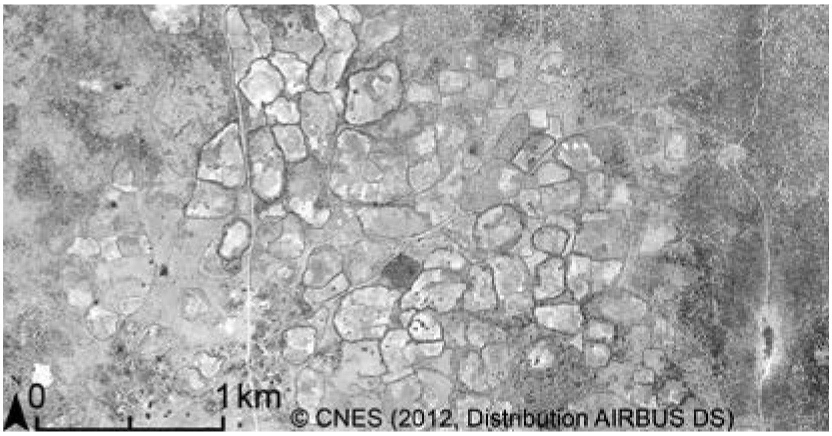


Figure 4.8: Satellite image of a section of the research area in the Mahafaly region, Madagascar. Around the villages (lower left corner) a network of hedges surround cultivated fields. The cultivated land has expanded into the forest (right). In between the fields, existing patches of forest are connected with the larger forest through hedges working as corridors, providing a suitable habitat for many animal species, and maintaining high levels of biodiversity in the human-used landscape. (Joachim Nopper)

Keeping vegetation above this threshold by retaining woody vegetation stabilizes reptile species richness to a certain degree. There need to be structural elements in the landscape such as hedges acting as fences along agricultural fields, or remaining natural vegetation: these play a very important role in maintaining high reptile species richness. The inclusion of these structural elements in cleared and unconnected landscapes might establish links (i.e. corridors) between remnants of natural forests and enhance connectivity within the human- utilised landscape (Nopper et al. submitted) (Figure 4.8). Habitat availability for these forest-dependent species could additionally be increased by including sacred and community-managed forests into management concepts and linking them with other forests through corridors (Ferguson et al. 2014). A proposed way forward is to establish a network of protected sites that are connected by corridors of suitable landscape elements using remaining community forests as nuclei. Alongside the human-utilised landscape, the protection of continuous forest habitat remains essential to maintain viable populations of all species (Nopper et al. submitted).

At present, the most promising concept to reconcile biodiversity conservation with agriculture, provisioning of food and other forest ESS is agroforestry, in which woody perennial vegetation is integrated into cultivated and grazing areas (see Chapter 1 page 44). Even though these landscape elements positively affect biodiversity in the human-utilised landscape, they also consist in parts of exotic species whose effects on the natural ecosystem are yet little understood. Those exotic species need to be monitored closely, and managed, in order to prevent uncontrolled distribution, and becoming invasives (Gérard et al. 2015; Nopper et al. submitted).

4.2 Paying for ecosystem services

Biodiverse landscapes and land management practices have a number of benefits for ecosystems function and services provided to people. In systems focusing on agricultural production, the inclusion of biodiversity has its merits as demonstrated through conservation agricultural practices, on grassland and forest land use (see Chapter 1 page 24), or in combination with climate change mitigation for carbon sequestration (see Chapter 3 page 84).

However, in biodiverse landscapes, in comparison to biodiverse land management systems focussing on agricultural production, the economic benefits are much more difficult to assess and present a less convincing case for investment of time and care by land users. In cases where ecosystem preservation has costs for those who are ensuring it, or where this limits the 'profitable' use of the land (for farming etc.), compensation or incentives are needed. This is the focus here. Some examples investigated by research are:

- Biodiversity and disaster risk reduction in the coastal region of North Germany
- Design of Payment of Ecosystem Services (PES) in the VGTB basin in Vietnam and the Mahafaly Plateau in Madagascar
- Marketing a natural heritage (highland production systems in the Philippines/ Vietnam)

Benefits from combining biodiversity and climate change adaptation in the coastal region of North Germany

Biodiversity co-benefits from adaptation to climate change need additional payments for eco-system services in the coastal region of North Germany

context: large-scale industrial and or intensive agriculture reduces biodiversity in lowland and coastal areas

problem: many former indigenous species are extinct and the natural vegetation is only present in small, conserved remnants of the former coastal landscape

solution: rewetting of drained cropland and less intensive land use of grasslands will improve biodiversity; besides the income from agricultural land use, the benefits from high levels of biodiversity and natural vegetation (e.g. for climate mitigation, tourism and recreation) should be valued in decisions about future land management

message: Direct rewards from biodiversity are often not enough for people to invest in conservation: they further need to be compensated by payment for ecosystem services (PES)

In Chapter 3 some co-benefits of biodiversity with climate change mitigation practices have already been indicated. However here, the focus is on examples of co-benefits and trade-offs of biodiversity with climate change mitigation as well as climate change adaptation as investigated by research.

Along the European coastline agricultural intensification has taken place. Coastal wetlands were drained and 'impoldered', then converted into intensive agricultural land for dairy farming and crop production. Large-scale industrial and intensive agriculture reduced biodiversity in these areas. Many former indigenous species are extinct and the natural vegetation is only present in small remnants within conservation areas.

Rewetting of drained cropland in combination with less intensive land use of grasslands will improve biodiversity along the European coastline. Biodiversity of several land use types was measured for each separately based on the plant rarity index (Figure 4.9). The plant rarity index is the occurrence of endangered plant species and typical species of endangered habitat types based on the IUCN 'Red List of Threatened Species' and the 'European Commission's Habitats Directive Annex I' (Box 4.2).

Box 4.2: Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

The directive aims to protect some 220 habitats and approximately 1,000 species listed in the directive's Annexes. These are species and habitats which are considered to be of European interest, following criteria given in the directive. It directs Member States of the EU to take measures to maintain the 'favourable conservation status' of protected habitats and species.
(http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm)

Biodiversity increased in the wetter land use and vegetation types, except for the very wettest situation, when the land was submerged and reeds were prevalent: here the wettest zones showed the lowest plant rarity index with few endangered plant species. However, reeds achieved the highest carbon sequestration results, illustrating that in the case of reeds, there is a trade-off between CC-mitigation and biodiversity. The wet grasslands showed the highest plant rarity index of flood protected agriculturally used pastures. The highest plant rarity index with greatest numbers of endangered plant species, and hence high biodiversity, was found on salt marshes. Salt marshes are coastal wetlands that are flooded regularly by salt water brought in by the tides.

Water retention areas and de-embanked parts of the landscape (that are exposed to increased flooding), with extensive or abandoned land use or mixed/combined with intensive agricultural land use, may be especially effective in increasing the biodiversity of plants in the region. A diverse mosaic of different land uses and natural wetland areas will be created where the land use is adapted to increased flood risks. It is projected that this will lead to increased biodiversity and resilience to climate change risks and disasters with diverse additional services including recreation, and increased tourism.

Re-wetting for combined CC-mitigation and CC-adaptation presents an example of productive Eco-Disaster Risk Reduction (DRR) (see Chapter 3 page 81). Where intensive agricultural land use is no longer possible due to rising water levels and flood risks, an increase in the area with former natural coastal habitats will take place. Although abandonment may lead to decreased plant biodiversity (for example reeds instead of grassland), animal biodiversity may increase as reeds are the natural vegetation in the region. The abandonment of these sites will also strongly increase the resilience of the landscape to climate change risks (see Chapter 2 page 70).

The plant rarity index is used as an indicator of biodiversity, meaning the higher the index the more endangered plants species are present and the greater the biodiversity. Four land management scenarios modelled under climate change (IPCC climate projection: SRES A2; sea level rise 1.05 m till 2100; Meehl et al. 2007) illustrate the impact on biodiversity and the great differences as a result of management (Figure 4.10):

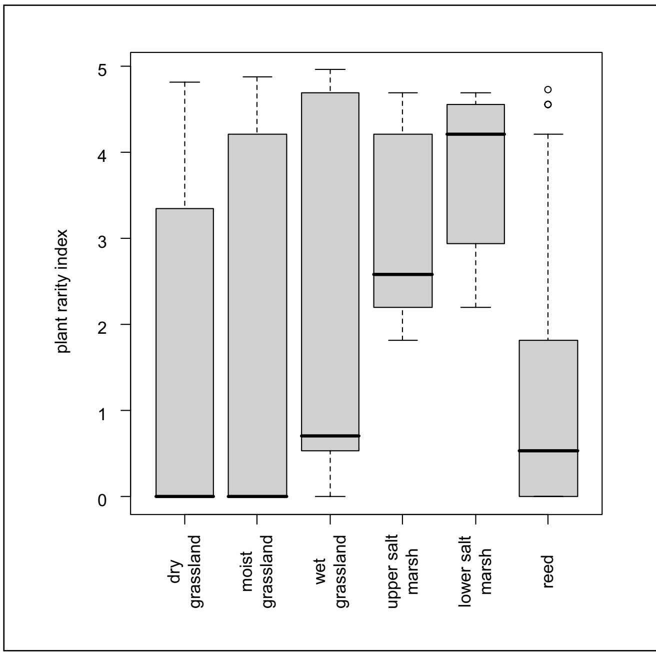


Figure 4.9: Plant rarity index (based on number of endangered species and typical species of endangered habitat types) within different grassland types, coastal salt marshes and reeds in Germany, the Netherlands and Denmark. The land use and different vegetation types are listed from the dry conditions (left) to the very wet conditions (right). Note: high plant rarity index means many endangered species are still present demonstrating high biodiversity. 0 plant rarity index indicates no endangered species. (COMTESS)

- The red line shows the scenario of the 'business-as-usual' trend (i.e. dairy farming and crop production). In the model, pumping capacity is unlimited and costs are not taken into consideration. It will be very expensive, but it should be technically feasible if the costs are covered.
- In comparison, the blue line shows the situation after de-embankment of large parts of the peninsula with adapted agricultural (extensified grazing) and non-agricultural land use.
- The yellow line shows the development of plant rarity index for the land management option developed by local stakeholders: slightly less intensive land use than 'business-as-usual' or mixed with more extensive land uses. It shows higher values and therefore a greater number of endangered plant species compared to the business-as-usual.
- A landscape optimized for carbon sequestration (green line) shows low numbers of endangered plant species due to the high amount of reeds.

As adaption to climate change and increase of biodiversity will be by extensification of agricultural use and at the cost of intensification, the loss of productivity will have to be 'paid for' by other services provided such as tourism and recreation, or by additional payments for ecosystem services.

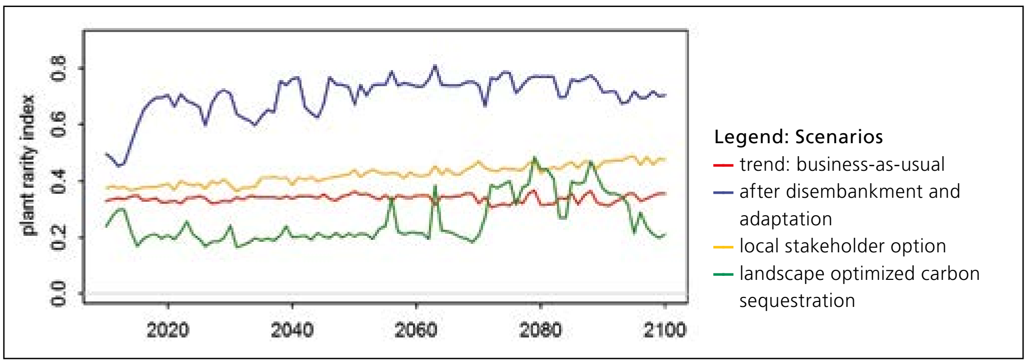


Figure 4.10: The plant rarity index up to 2100 for the peninsula of Michaelsdorf in the Baltic Sea, Germany modelled for four different land management options (IPCC climate projection: SRES A2; sea level rise 1.05m to 2100; Meehl et al 2007). (COMTESS)

PES - Combining climate-smart agriculture with biodiversity in Vietnam

PES for sustainable agriculture and reducing deforestation: REDD+ and Climate-Smart Agriculture in landscapes
context: expansion of rice and acacia plantations for subsistence and cash crop production
problem: (i) lack of fertile land for local needs, (ii) deforestation and forest degradation cause GHG emissions
solution: agent-based modelling to identify viable landscape management strategies / combinations of measures to reduce pressure on the forests such as: – Tephrosia fallow to store carbon and increase rice yields by nitrogen fixation – recognition of land ownership! (land use right certificates) to provide incentives for innovative land use and management – REDD+ reducing Emissions from Deforestation and Forest Degradation – Climate-Smart Agriculture (CSA) – cross-sectoral policies
message: deforestation problems are not simply answered by planting more trees: a mixed response is required, addressing the root of the problem

Research conducted in the Vu Gia Thu Bon (VGTB) watershed in Vietnam aimed at identifying land management strategies such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) and Climate-Smart Agriculture (CSA) to reduce emissions from deforestation and to adapt to climate change.

The research was carried out under a case study in central Vietnam (Tra Bui commune, Quang Nam province) to identify landscape management strategies that achieve forest protection while improving agricultural practices and adaptation to climate change. To this effect, workshops with local communities were convened to understand the land management decisions of local farmers. The information has been used to simulate impacts of land use decisions in landscape dynamics, and the associated carbon emissions over 30 years. An agent-based model (ABM) simulates the actions and interactions of autonomous agents (both individual and collective entities, such as organizations or groups) with a view to assessing their effects on the system as a whole. They simulate the simultaneous operations and interactions of multiple agents in an attempt to re-create and predict the appearance of complex phenomena.

In the study area, deforestation was mainly driven by the expansion of land for rice cultivation to satisfy food needs, and by the establishment of acacia plantations as a cash crop. The study explored five land management scenarios (Figure 4.11). One of them, a CSA technique named 'tephrosia fallow', is used for the sustainable intensification of rice production (Box 4.3). Tephrosia fallow increases yields in existing agricultural areas, and firewood production in the woody fallows, and therefore is expected to reduce deforestation related to agricultural expansion, and forest degradation related to firewood collection.

The recognition of land ownership was found to play a major role in the implementation of tephrosia fallow via the provision of Land Use Right Certificates to all farmers. Such certificates are needed because the time needed for the implementation of the CSA technique implies investments in land which farmers are willing to make – but only if their land ownership is recognized.

Another scenario explored was Payment for Ecosystem Services (PES) obtained under the REDD+ scheme to reduce deforestation. Since an increasing amount of natural forests is being replaced by profitable acacia plantations, the maintenance of natural forest needs to be economically supported.

The scenario combining PES and CSA (PES_CSA) resulted in the lowest carbon emissions, because deforestation due to acacia plantation and rice expansion was minimized. The second-best scenario combines CSA with forest protection measures (ForPro_CSA), where all farmers adopt tephrosia fallow, which increases yields while storing carbon on the fallow land, and stricter forest protection reduces deforestation for rice cultivation.

Box 4.3: Tephrosia fallow
Tephrosia is a nitrogen fixing plant belonging to the pea family and improves soil fertility. Tephrosia fallow is expected to increase the yield of rice plantations up to 19% and store more carbon in fallow land, up to 9.6 t/ha/year (Salvini et al. 2016).

Results showed that forest protection and rural development strategies can, and should, be combined and that policies aimed at improving adaptation to climate change are more effective if implemented in synergy with CC-mitigation policies. This is currently hampered by a sectorial approach in land management: in Vietnam policies aimed at agriculture management and forest protection are designed and implemented separately by two different government departments. Thus, there is a strong need for better cross-sector cooperation and coordination to facilitate the establishment of REDD+ schemes.

Combining PES with REDD+ in dry forests of Madagascar

Protection of Madagascar's remaining dry forest
context: deforestation leads to GHG emissions and biodiversity loss
problem: dry forest has a lower C storage capacity than forests in wetter conditions -> incentive for REDD+ is too low
solution: adequate subsidies / PES, adapt REDD+; PES that also include ESS other than carbon storage (as in REDD+) such as conservation of biodiversity
message: REDD+ and associated PES systems have been widely promoted as an answer to forest degradation – however in certain specific situations, like low-carbon content dry forests, they are complex to design and put into practice

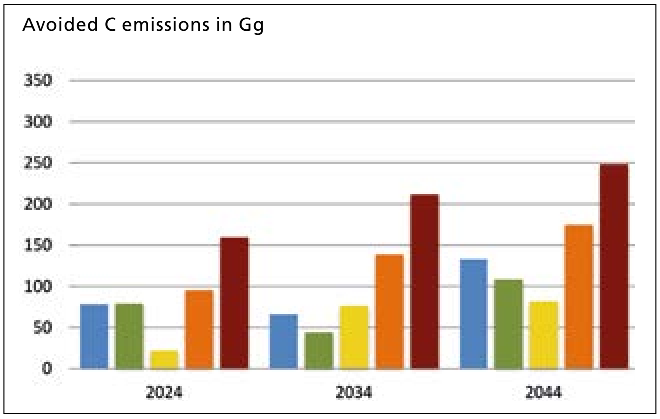


Figure 4.11: Avoided carbon emissions (in Gigagram/Gg) for different policy scenarios and over 20 years starting from 2024, Vietnam:
PES_AC: implementation of PES for avoiding acacia plantations (blue);
ForPro: implementation of stricter forest protection (green);
CSA_Tephrosia: implementation of tephrosia fallow (yellow);
ForPro_CSA: implementation of strict forest protection and tephrosia fallow orange);
PES_CSA: implementation of PES for avoiding acacia plantations and tephrosia fallow (red). (adapted from Salvini et al. 2016)

Figure 4.12: Dry spiny forest towards the coast of the Mahafaly area in Madagascar. (Johanna Götter)

Figure 4.13: Traditional irrigated rice terraces: rice transplanting in Batad, Philippines (Martin Wiemers)

The dry forest area of the Mahafaly region in Madagascar has been reduced by 45% over the last 40 years (Brinkmann et al 2014). The protection of the remaining dry forest area in the Mahafaly region of Madagascar would contribute to the mitigation of climate change (Figure 4.12). In that context, REDD+ is often presented as a promising mechanism to halt the ongoing deforestation and degradation of natural forests. But REDD+ focuses on forest carbon stocks as a means to calculate economic incentives for forests. The above-ground carbon stock of dry forests was estimated to be 7.9 t C/ha. This is very low compared to other tropical forest ecosystems reaching 99.5 t C/ha for humid forests in northern Madagascar, with undisturbed forests harbouring more than 140 t C/ha above-ground (Asner et al. 2012). Consequently, REDD+ activities focus more on those forests ecosystems that store high amounts of carbon. To be effective, for the conservation of the dry forest ecosystem of the Mahafaly Plateau, REDD+ schemes have to be adapted and/or complemented by identifying alternative schemes of payments for ecosystem services that encourage biodiversity conservation instead of solely focusing on the prevention of carbon emissions.

Marketing agrobiodiversity and a natural heritage in rice production systems (Philippines)

Tourism to preserve agrobiodiversity and attractive agricultural landscapes

context: abandoned highland rice terraces can lead to reduced interest within the community to preserve the forests and their biodiversity. Forests are source of continuous water supply

problem: traditional highland rice terraces are abandoned because they are economically not viable and involve high workload. Migration of youth to nearby cities to work in tourism. Loss of agrobiodiversity

solution: income from ecotourism re-invested into terrace maintenance and reaches farmers, re-introduction of and marketing strategy for local rice varieties which attract higher prices (quality instead of quantity, 'branding' or 'source-labelling'); indirect incentives for forest protection (production system relying on natural system)

message: ecotourism, or 'agro-ecotourism' is a novel idea to attract investment into historical terracing to ensure its upkeep. This can be associated with branding of products

Abandonment of rice terraces in the highlands of the Philippines threatens an ancient sustainable land use system (Figure 4.13). It is not only a mix of a natural and cultural heritage but - because of its close dependence on well-managed water resources from the rainforests - it helps to conserve rainforests with high biodiversity in the mountains above the terrace systems. When rice terraces are abandoned, the interests of the community in continuous water supply from those forests is reduced and there is the risk of loss of interest in preserving the forests.

Maintaining and planting a range of local rice varieties (or 'landraces') in traditional terrace systems of Vietnam and the Philippines would contribute to protecting agrobiodiversity within the overall rice system (Figure 4.14). Marketing of those more flavoursome and 'special' local rice varieties, which command higher price at local markets – for tourists in particular – can be improved by branding, that is developing a special label for them. Such a strategy can increase the production value of and the interest in maintaining the terraces systems.

In combination with special varieties, agroecotourism in irrigated rice terraces and paddy fields with local/ indigenous rice varieties could render rice cultivation in mountain areas once again more attractive and viable to land users (Figure 4.15). It is one of the most promising options to support the continuation of a cultural heritage site, but simultaneously as a valuable production system enhanced by income generation from tourism. But income generated from ecotourism does not necessarily reach the local rice farmers. The management of the sites needs to ensure that the income generated is re-invested into maintaining the terraces. For example, at one of the most attractive sites, the Batad rice terraces in the Philippines, visitors are asked for an entrance fee, which is distributed among the farmers.

Figure 4.14: Marketing of local rice varieties, Vietnam. (Stefan Hotes)

Figure 4.15: Ecotourism – Walking the Banaue rice terraces, Philippines. (Martin Wiemers)

Conclusions

Lessons learnt for protecting biodiversity and ecosystems

Biodiversity loss takes place when forests and semi-natural systems are converted to any type of agricultural land, such as conversion from:

- forest or wetlands to grassland;
- grassland / wetland to cropland;
- diverse cropland to monocultures (intensification);
- small-scale (multiple patterns within the landscape) to large-scale single pattern without differentiation within the landscape.

Research shows that in general biodiversity gets poorer, as the more specialized and intensified agricultural use becomes.

Not only conversion of land, but also overuse and fragmentation of natural and semi-natural ecosystems/ habitats such as forests, woodlands, and steppes lead to an impoverishment of biodiversity.

However, biodiversity can again build up 'naturally'. Abandonment of semi-natural and previously agricultural land, for example, while managing invasive species, can lead to an enrichment of previously poor biodiversity.

Very often the importance and 'state' of biodiversity in a region is not known to a community or the local government. If there is no awareness about the problem and the benefits of solving it, then it is hard to find appropriate solutions, particularly if the main concerns are related to productivity and production. There is a trade-off between preserving ecosystems and biodiversity and ensuring livelihoods or maximizing profits.

Awareness-raising and education about the values and benefits of sustainable management of natural and semi-natural land use systems on biodiversity is badly needed: "we protect what we know" drawing attention to so far unrecognized biodiversity. Involving different land users and the public in monitoring of the benefits of protection is needed.

How much can, and will, be done in one direction or the other will depend on the benefits and incentives offered to spare land for biodiversity purposes, or the direct benefits from integrating biodiversity into the productive system itself. This could include hedges as biodiversity corridors, mosaic landscape with extensified patches, biological pest management, landraces and local varieties as cultural heritage, etc.

Mix of different and complimentary strategies to preserve and protect ecosystems and their biodiversity

- Strengthening the protection of natural and semi-natural systems:
  - through the creation of protected areas, and monitoring and reinforcement of rules and regulations;
  - by avoiding fragmentation and creation of diverse habitats and ensuring connectivity by corridors and mosaic landscapes;
  - through payment for ecosystem services and providing incentive structures for continued management of natural and semi-natural systems;
  - via climate change mitigation incentives/ payments as an additional benefit for the protection or re-naturalizing of intensively used land.

- Sustainable land use and management (inherent in most of the other practices presented in Chapters 1-3) will protect or improve agrobiodiversity
  - as an integral part of the production systems (e.g. conservation agriculture, agroforestry);
  - as part of sustaining livelihoods (e.g. diversification in production for home consumption and to reduce risk of production failure);
  - as a synergy or by-product of a practice focussing on other 'goals' such as climate change adaptation/ mitigation (e.g. good soil cover, good soil structure, high biomass production).

- Sustainable intensification in agriculture and settlement is a viable strategy to spare land/ natural vegetation for biodiversity protection.

- Increase agro-biodiversity through diversification within an agricultural system and combine with diversification of agricultural systems within the landscape.

- Involvement of land users and the public in monitoring biodiversity and its benefits in order to get people's support and involvement.

CHAPTER 5

Bridging gaps between research and practice

Brazil, Stefan Hohnwald

Introduction

The necessity to 'bridge gaps' between research and practice has played a particularly prominent role for at least the last 400 years. It was in 17th century Britain that members of the National Academy of Sciences defined 'pure' research as leaving out anything that can be directly impacted by human behaviour, the arts, culture, or, at that time very importantly: 'anything that has to do with the realms of faith and conviction': in other words the church and religion. It was the idea of pure, objective knowledge emanating from the natural scientists' laboratories that led to the great discoveries of the laws of nature. And it was this kind of knowledge created in physics, mechanics, and chemistry that took root in engineering and served as the backbone of industrialisation in Great Britain and other nations.

Today's land management and land use challenges are of a very different nature. Human intervention and human interaction with the land is what it is all about. Human intervention has long been the key driver of change: be it the loss of land, land degradation or the many options for using land more sensibly, it is mainly humans who can destroy or degrade, or innovate and manage sustainably. Yet to this day, scientific knowledge as displayed in mathematical equations, models and scenarios, or set out in academic papers, is neither readily accessible to, nor easily understood by non-scientists. But the converse is true also: often enough scientists do not understand the necessities of economic survival of small-scale farmers, nor comprehend the depth of knowledge of local communities living for centuries on, and with, their land: the same indigenous knowledge that helps to balance out human interaction with the interest of long-term conservation of the land and its waters.

Bridging these gaps therefore remains a basic challenge between scientists and non-scientists and between academic/ scientific knowledge and the knowledge of non-scientists: the practitioners and implementers of land management and land use. In the latter group we can list:

- farmers or other land users;
- advisory or extension services;
- public administration/ governmental organisations;
- policy-makers (local, regional, national);
- non-governmental organisations;
- the private sector/ business;
- others (e.g. churches, unions).

However, it must be understood from the beginning that 'stakeholders' include the researchers. Admittedly they do have their own interests when it comes to running an implementation-oriented research project – be it the conduct of a PhD thesis, carrying out experiments and interviews for this purpose, or the publication of academic papers. It is fundamental though to understand that 'scientists' and 'non-scientists', while they may have different primary interests and objectives, are equally embraced within the term 'stakeholders'.

Guiding questions

In the context of bridging the gaps between research and practice, this chapter attempts to answer these two questions:

- How can we make knowledge from research more approachable and better understood by non-scientists?
- What methods and tools are available to bridge some of the many gaps between research and practice?

The main issue concerns in particular the gaps that exist between research outputs and implementing results at various spatial levels. It covers basic information about the land, knowledge about options for improved land management, as well as ideas and suggestions for possible implementation. Often, in research projects, basic collection of data in the framework of land management research is conducted by PhD candidates. Their basic interest is to assimilate data from field research or from interviews with local stakeholders and to use these data for writing their PhDs. The demand for information and knowledge by those local non-scientific stakeholders – farmers, land managers, field agents and so on – is very different. They need to know (for example) what can be done differently in order to increase profits from agricultural products. Or what they can do to reduce basic input costs of labour, energy, water, fertilizers or 'agricides'.

Fortunately, these interests can beneficially interact. The data from the scientists can, generally speaking, be useful in one way or another for the information and knowledge needs of non-scientists. But those data are usually not accessible in their current academic forms and modes of expression. And commonly the questions that practitioners of land management are interested in are not addressed right from the beginning by the scientific research work: research isn't 'demand-driven'. It needs well-prepared communication to make the needs for knowledge of land users (and other practitioners) understood by scientists. And vice-versa: it needs equally good communication of the scientists' interests so that the non-scientists can relate to that.

This chapter focuses on some approaches, methods and tools that have been tested out in the seven-year time frame of the BMBF-SLM programme. They are illustrated by selected examples from the research projects to give an idea of what has proved possible under the current framework conditions for implementation-oriented research. It starts with 'awareness-raising' and 'capacity building' as means for involving practitioners in the work of research and enabling them to relate to it. Capacity building here implies both helping land management practitioners understand the work to be undertaken by the scientists – and equally to make it easier for the scientists to understand exactly what land management practitioners are interested in.

The chapter further describes elements of 'framework conditions and governance'. Here the focus is in particular on insufficient legal and policy frameworks. What kinds of governance and institutions are needed to support sensible implementation of land management options and to create an enabling environment for SLM practices? The section 'Use of Knowledge' then describes some possible routes for knowledge – from its initial function of filling knowledge gaps, then enabling cooperation and participation, to better informed decision-making. Finally the chapter rounds off by shedding a little more light on the overall challenge involved: 'Stakeholder integration' and 'Co-production of knowledge' between scientists and practitioners and implementation-oriented users of knowledge. This requires much better and more suitable frameworks than those we generally find today in the worlds of science and research.

Happily, steps in this direction are possible, against all the odds. Some of those options are described in the last section and in the conclusion of this chapter. The steps described in this chapter are still small, but important never-the-less in making better sense of the more and more rigid frameworks set out by funders of science when requiring inter- and transdisciplinary as well as implementation-oriented research. For the scientists and practitioners involved, these framework conditions still need many adaptations to achieve lasting success from this kind of research (see Chapter 6 page 129).

5.1 Awareness-raising: communicating complexity

We take land for granted. Unlike mountains and beaches, land as such is often just 'there'. Yet it has never been easy to make a living from the land and the fertility of its soils. Lack or abundance of water (floods, droughts etc.), combined with mismanagement with resulting erosion and desertification are major problems for humankind. These everlasting challenges for farmers to sustain their livelihoods, while holding custody of the environment, are not at the center of public awareness. Generally speaking there is a deep lack of public awareness regarding the problems connected to land management and land use. This concerns, in particular, the consequences of human management of land: what crops are planted, whether crops are rotated over the years or not, how the land is cultivated for crops and/or animal herding, how water is – or is not – managed sustainably, what harvesting technologies are employed and so on. In sum all these single aspects have an enormous impact on the quality of ecosystems consisting of soils, water and vegetation, and perspectives and options for their future use.

Even with farmers themselves, understanding of the interrelatedness of these challenges and their long-term impacts is often not very high. They see their fields. They have developed methods and skills to make most of what they have and view. But the repercussions of climate change, resulting water scarcities or abundancies (as with floods or rising sea levels), or the impacts of the global food and energy markets, are often not easy to comprehend. This provides a large challenge for awareness-raising. Land matters. In many respects and dimensions. And for many people in very different ways. But it is not clear who is aware of what problems. And what problems and challenges need to concern whom. The first step for scientists working in implementation-oriented research therefore is to find out about the current state of 'who wants what? That is: what interests are involved?'

Lack of awareness and education

Lack of awareness takes place at several levels. First, there is the land users' awareness of the state of their land and environment, such as importance of land properties or water quality. But often there is poor awareness about the role of natural fauna and flora in 'agrobiodiversity', for example the function of a productive biodiverse landscape to foster natural predators such as parasitic wasps and spiders for regulating pests. Often this lack of awareness is related to the level of education, a limited access to knowledge and exposure to alternatives (e.g. through the media). Post-school education in some regions is almost non-existent, and often people have not updated their knowledge base for some decades. School teachers are generally badly paid with little or no incentive for any efforts for improvement of skills. Pupils suffer as learning is impaired.

Lack of support

Secondly there is a common lack of capacity and organizational competence at institutional level. There is a special need for awareness-raising and capacity building within governmental extension and advisory services. They do offer technical and organizational advice and support, training courses, information material etc. but they are often crippled by lack of funding. In some cases these services are taken over by NGOs, or fertilizer companies, or by companies selling technical equipment and machines to farmers. This

Figure 5.1: Video station at the exhibition LAND USE LIFE at the Thünen-Museum-Tellow, Germany. (Anne Kirstin Baumgärtel)

Figure 5.2: Exhibition LAND USE LIFE at the Thünen-Museum-Tellow, Germany. (Anne Kirstin Baumgärtel)

can work in favour of soil conserving technologies when a no-till machinery company offers machinery service and advisory support. But powerful lobbies can also attract awareness and knowledge generation in an opportunistic manner, just as the chemical industry does with respect to pesticides or with fertilizers in intensive rice production.

Lack of long-term perspectives

Thirdly, lack of public awareness about ongoing and future changes, and their impact in the near and distant future is a major impediment to searching for and developing promising and more sustainable solutions for better land management. This holds particularly true for tasks that are not currently pressing. Challenges of longer-lasting change such as the climate and loss of biodiversity are especially difficult for land users and their supporting groups (such as extension services) to deal with. With present trends continuing, in nearly all the researched regions of this BMBF-SLM programme there will be long-term repercussions, turning these challenges into urgent and pressing problems which jeopardize economic survival.

5.1.1 Outreach approaches and material

Awareness-raising events, campaigns and information material are key to sensitize stakeholders and the general public towards specific themes such as loss of biodiversity, increasing pollution, or degradation of ecosystems – and to alert people to possible solutions and innovations. Suitable information material ranges from scientific journal papers for the local and national scientific community, to guidelines, reports, videos and posters targeted at decision-makers. Policy briefs and press releases focus more on the broad media and general public, as do more 'popular' leaflets, fact sheets, podcasts and videos etc. Recent developments in information and communication technologies, such as blogs and the use of social media such as Twitter and Facebook (e.g. https://facebook.com/innovate2012/9), provide new opportunities for awareness-raising, broader dissemination of useful information, and sharing of knowledge and experiences. However, all information that aims to contribute to successful awareness-raising needs to be fine-tuned to the very diverse target groups involving scientists, local communities, decision-makers and planners. Each of these target groups needs specifically tailored awareness and training materials: from analytical fact sheets laying out issues and options supported by clear data for high level decision-makers, to simple visuals including comic books and videos in local languages where literacy levels are low. Communication measures need to adapt to circumstances.

Examples

LAND USE LIFE exhibition and films

In Germany most people do not have direct experience with land use besides outdoor recreational activities. Therefore, general public awareness-raising videos were produced and an exhibition called LAND USE LIFE was created. The exhibition (Figures 5.1 and 5.2) demonstrated that land use change is ongoing because of changing societal demands and challenges. The most important initial challenge has been the increasing demand for food, and fodder for animals. Later on, recreational activities became more important; and now there are new demands, such as that for increased production of bioenergy, or initiatives to increase carbon sequestration to mitigate climate change. All are addressed in the exhibition. The videos and the exhibition aimed to raise perception of individual consumption habits and how it can have an effect on land use and land use change (see videos at http://www.cc-landstrad.de/publikationen/informationsmaterial/videos/)

Jointly developing dissemination material

For the development of dissemination products (Figures 5.3 – 5.6), several workshops were organized on the Mahafaly Plateau in Madagascar in which researchers worked jointly with farmers, rural communities, NGOs, universities and state agencies on solutions to support sustainable land use. The most promising recommendations, techniques and approaches were finalized after validation through stakeholders, project partners and the scientists involved. In this context the local partners (World Wild Fund - WWF, Madagascar National Parks - MNP) that will continue their work in the region were important addressees and mediators for further optimization and long-term application of SLM approaches and techniques.

Key recommendations disseminated included improved technologies for sustainable crop and fodder production and income diversification to reduce the risk of crop failures, the establishment of long-term community-based monitoring schemes (e.g. on biodiversity), enhancing knowledge transfer and capacity building, as well as raising environmental awareness.

Delivering information about water quality management

In the dry south-western region of Madagascar, limited water availability and poor water quality considerably restrict the potential for the development of sustainable land management alternatives – as well as constituting a serious public health problem for the local population. To support future management interventions, information about the water quality of local sources was obviously essential. A sample of 30 wells throughout the study area showed that

Figure 5.3: Presentation of final products in the village workshop, October 2015, Madagascar. (Katja Brinkmann)

Figure 5.4: Workshop on product development, Madagascar. (Katja Brinkmann)

over 96% contained some kind of coliform bacteria (Rasoloariniaina et al., 2015). The reason is that the local water sources, such as wells, are simply not well managed. Local inhabitants have multiple demands on water including drinking, watering their livestock, washing clothes, and bathing. If this is not controlled, it leads to high degrees of contamination of most sources.

As options for increasing water availability by exploiting new sources are limited in the region – which might diminish the problem, though not solve it entirely – it is crucial to avoid further contamination of existing water sources. In order to raise awareness about water management procedures that separate sources for human drinking supplies from livestock watering, bathing and washing garments, a simple illustrated brochure was developed and disseminated (Figure 5.7).

5.1.2 Environmental awareness and education

Comics for new management practices

A specific tool for environmental awareness-raising and education purposes is comic-style illustration of visual narratives (see Approach 'Comic style environmental awareness' page 235). In a situation of high illiteracy rates like rural Madagascar these illustrations were used to support the communication of scientific results and recommendations on sustainable land management. They helped to facilitate knowledge transfer from scientific experts to local people and vice-versa, and to discuss land use change and possible alternative technologies with them. The comic illustrations show the impact of different land use practices on the environment and local livelihoods using two contrasting stories/scenarios. A worst case scenario of unsustainable land use techniques that were often applied by local inhabitants, and an example of a best case scenario based on an alternative, sustainable land use option recommended by scientists. The latter included the use of composted manure for home gardens and increasing awareness of animal hygiene (especially the need for frequent removal of dung from night corrals).

The comics demonstrating a simple way of comosting manure (Figure 5.8) or showing a sustainable harvest technique of wild yam (see Chapter 1 Figure 1.66 page 45) were assessed in terms of perception, comprehension, and willingness to implement the recommendation. The evaluation was conducted through semi-structured interviews and focus group discussions in three villages. Most of the participants (80%) were aware that the traditional harvesting technique may negatively affect wild yam regeneration, and they agreed that the recommended sustainable harvesting technique could maintain or even increase the wild yam resources. They were interested in testing the recommended technique. However, interest was not matched by action – and actual implementation was relatively low. Only 20% of the respondents were convinced that sustainable management could enhance long-term profits. This reservation was particularly based on realising that additional labour inputs would be required for the more sustainable technique, with labour resources already very constrained for subsistence smallholders.

Figure 5.7: Brochure disseminated to raise awareness of cost-efficient and effective measures to improve water quality – in the local language (Malagasy), Madagascar. (Jean Robertin Rasoloariniaina)

Figure 5.5: Distribution of comic style illustrations, Madagascar. (Katja Brinkmann)

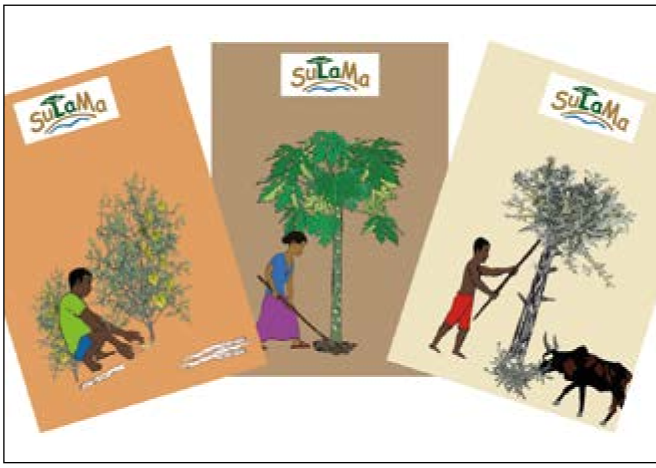


Figure 5.6: Comic-style illustrations of visual narratives. (designed by David Weiss)

In addition, informative documents and maps were used to raise awareness about the cultural dimension of land management: taboos, clan landscapes, socio-cultural rules and beliefs, amongst others. During this work it became much more obvious how very different the cultures and value systems of researchers and the local population actually were. The scientists oriented their research along a 'western concept' of sustainability, aiming first at conservation and protection of the natural resource through scientific methods. In contrast, from a local point of view, sustainable resource use means to be in balance with supernatural beings, natural spirits and ancestors, who influence the success or failure of all their activities. There were guidelines in form of ancestral rules and taboos which prohibit using certain species of plants and animals, or against entering or polluting certain places.

A short socio-cultural checklist provided critical questions and practical recommendations on how to design written material that pays tribute to local worldviews while respecting privacy and dignity. The checklist gave advice on how to develop understandable and usable products for stakeholders, while taking account of the local and regional culture and belief-systems. Awareness-raising on sustainable land use took also place in Germany. Here a project started a travelling exhibition at the Zoological Institute in Hamburg (April 2016) including poster presentations, products and video clips describing biodiversity, land use problems and sustainable alternatives in Madagascar.

5.1.3 Use of media: TV series/ participatory awareness filming

Soap operas for biodiversity

In Vietnam, a TV series illustrated the role and importance of biodiversity in rice-dominated landscapes. This media campaign was conducted in Vietnam (Figure 5.9; see Approach

Figure 5.8: The comic story demonstrates a simple way of composting manure and how it can be applied to improve soil fertility and yields in home gardens. The comic describes two contrasting scenarios on the local use of manure. The 'red scenario' (top) depicts the current situation, where local people are not removing manure from the corrals and also missing the chance to use it for fertilization. In the 'green scenario' (bottom) the farmer is regularly cleaning the corral and collects the manure for composting in a heap next to the corral, Madagascar. (David Weiss)

Figure 5.9: Rice farmers in Trung Hoa village, Cha Gao district in Tien Giang province, Vietnam watching an episode of soap opera addressing biodiversity. (https://ricehoppers.net/page/8/)

Figure 5.10: Three of the comedians reprising a scene on stage at a 'Meet the Actors Day' in Hieu Nhon village, in Vinh Long province, Vietnam. The sketch highlights a discussion between three farmers on insecticide resistance. (https://ricehoppers.net/page/8/)

'Entertainment-education for ecological engineering' page 267). Nineteen different episodes were broadcast, covering topics such as the agricultural ecosystem and forest trees, plant health, eco-tourism and eco-engineering, the importance of honey bees, organic matter decomposition, microorganisms, the food chain, and the role of silicon. Rice farmers' daily lives were taken as the background for the story-telling, in order to better demonstrate the personal benefits they could expect from regulating ecosystem services (Figure 5.10).

The farmers were involved in designing the series. They are the target group of the campaign as well as those who are principally meant to benefit from it. The series has been widely distributed and has clearly supported communication of the scientists' work within the project.

Participatory awareness filming

In the Okavango Basin, within Angola, Namibia and Botswana, 'participatory awareness filming' was used as a means to involve stakeholders and to communicate implemented activities to different audiences. Representatives of different local stakeholder groups including resource users, traditional authorities, and NGOs were trained and helped to direct and shoot videos, themselves, about their own concerns (Figure 5.11). Together with villagers from Mashare, Seronga and Cusseque, three documentary films depicting different resource-related activities such as farming, fishing, beekeeping as well as the relationship between wildlife and tourism were produced. The films were conceived and shot by the participants of film workshops, and organized together with the para-ecologists (i.e. members of the local community working as support, and intermediary staff, see below) in each of the research sites. Local stakeholders were trained in film-making by the scientists.

The films were then screened to local communities as well as to different national and international audiences, informing them about project activities and initiating discussion about environmental issues. The process of film-making generated altogether new insights about the activities and perceptions of local stakeholders, which was then fed back into the research project. It triggered discussions between, and among, scientific and non-scientific stakeholders and additionally constituted a platform for the negotiation of different, and even conflicting, perspectives (see videos at: http://www.future-okavango.de/videoalbum_main_tfo.php).

5.2 Capacity building

5.2.1 Capacity building and training

Capacity building and training can take place at land user, local, regional and national levels. Institutional and land user empowerment requires adequate capacity and training. Relevant training and capacity building, which is otherwise offered by extension and advisory services, involved many individual land users. The capacity building efforts of the research projects were, for example, conducted via farmer field schools, farmer-to-farmer exchange, and bilaterally between scientists and local stakeholders, local promoters of sustainable land management and supportive communities. To this end, all involved planners, decision-makers and implementation specialists needed specific training in the form of lectures, exchange fora and vocational training courses.

Examples

Field days and vocational training

In the Kulunda steppe, field days or vocational training courses were conducted (see Approach 'Field days' page 255 and Approach 'Vocational training' page 259). By presenting research activities and results in lectures, poster presentations, film presentations and by distributing information materials such as flyers, and brochures at these events, different stakeholders were informed about regional ecological problems. This included the problem of the so-called 'dust bowl' (drying up and loss of

Figure 5.11: Shared film-making with land users: Participatory Ethnographic Film-making, Okavango Basin. (Martin Gruber)

Figure 5.12: Summer school 2014 addressing monitoring of biodiversity in Madagascar. (J. Rakotondranary)

Figure 5.13: Information meeting with villagers/ presentation of manuring (comics) and improved water hygiene, Madagascar. (Katja Brinkmann)

formerly productive top soils), resultant economic and social problems (especially outmigration of young people) as well as concrete options and strategies for much more sustainable land management and use.

On the basis of this experience, and as a follow-up, short training films (5 minutes each) are being produced. They focus on 'regional sustainable development', 'agricultural technologies' (e.g. no-till farming), and the 'topographical effects' of these measures for the Kulunda landscape. The films are being produced by the research project with the help of a professional film company and in cooperation with the regional universities (Altai State University and Altai State Agrarian University), representatives of local/ regional farmers of the study area and a private company for farming technology, which also contributes to the overall funding. An important partner for making use and distribution of this material is the Altai Institute for Advanced Training in Agriculture. The video films will not only reach students (in the cooperating universities) but also farmers, farmer extension services and consultants.

Working with para-ecologists

Para-ecologists are members of the rural land user communities who are employed by the research projects as support staff in field research, as well as being intermediaries with the local population. In the Okavango Basin as well as the Mahafaly Plateau they benefited via participation and organization of regular training courses, whereas the scientists clearly benefitted too: The para-ecologists served as successful intermediaries with practical land management experiences and implementation interests of the local communities. Traditional knowledge, societal taboos or other cultural specifics became more accessible to the scientists via regular communication and joint work with the para-ecologists.

Training courses covered scientific approaches, methodological skills like translation, workshop facilitation, biodiversity assessment, crop yield measurements, and soil sampling. They also covered technical skills including use of computers, digital video and photo cameras, GPS, as well as management of technical equipment like soil moisture sensors and weather stations. Besides the technical skills, the enhancement of soft skills such as professionality at work, team building, conflict resolution, and intercultural communication also formed a central part of the training. Through their daily work and the training courses, the para-ecologists gained insight into research activities and the academic world. They were exposed to new experiences, and acquiring new fields of expertise, through travelling to new areas and countries. Last but not least the para-ecologists benefitted from earning a regular income that allowed them to make a living. Furthermore, three para-ecologists in the Okavango Basin were trained to produce a documentary video about their work to share some of the research outcomes with the land user communities in their area. The videos were published as DVDs, screened and discussed in the villages and widely distributed in the area by the para-ecologists for awareness-raising and capacity building purposes (see videos at http://www.future-okavango.de/videoalbum_main_tfo.php).

Mix of approaches for different target groups

In Madagascar, annual interdisciplinary summer schools for students were organized in cooperation with a national NGO. These summer schools were conducted with para-ecologists who showed students methods of monitoring and assessment (e.g. monitoring flagship species for the National Park agency). The 120 students from Malagasy universities who attended the summer schools within five years (Figure 5.12) gained important competencies, which they then could utilize in R&D initiatives in Madagascar. These training courses enabled them to more effectively work towards sustainable regional development. At the local level field experiments and feedback workshops were conducted together with people from rural communities. The communication between students and villagers during the field experiments and associated workshops was an important step towards sustainable implementation of alternative land use practices. Socio-organizers regularly organized information meetings on SLM (e.g. on improved animal hygiene, water management, charcoal use, and alternative fodder use) in the villages on the Mahafaly Plateau (Figure 5.13).

Education days and training methods

In three municipalities in Brazil, bordering the Itaparica reservoir in the São Francisco River Basin, education days (Figure 5.14) addressing different target groups were held and jointly organized by Brazilian and German researchers. The target was general environmental awareness raising for two target groups: (1) school children and their teachers and (2) local stakeholders from the Itaparia reservoir including institutional representatives, farmers, fishermen, and other local residents. For the school children, informative posters, games and a cinema session related to environmental awareness and education were prepared – for example focusing on water quality and species found in the region. For the local stakeholders, research results were summarized and main findings for the region were presented and discussed with the participants of these workshops.

For this occasion, guidelines were produced and research-practice workshops conducted. In addition comic-like and well-illustrated leaflets based on traditional narrative styles (Figure 5.15) were produced for specific topics such as taking care of frogs for biological pest control rather than excessive use of agrochemicals (see Technology 'Biological pest control' page 171; see videos at http://www.innovate.tu-berlin.de/v_menue/materials_for_stakeholders/).

Figure 5.14: School children on one of the education days, Brazil. (André Ferreira)

Furthermore, a series of methodology courses was conducted in close cooperation between the German research partners and the Federal University of Pernambuco (UFPE) at Recife. Here, methods useful for decision-support were especially focused on: constellation analysis (for better identification of current interests of key interest groups, and determination of existing conflicts as well as entry points for possible action), as well as modeling techniques (hydro-dynamic modeling, hydro-economic modeling, and eco-hydrological modeling). These methods were taught and discussed with students and governmental employees to pave the way for real world application, and potentially beyond the realms of the current research project.

5.2.2 Monitoring and assessment as decision support

In order to prove beneficial impacts on improved land management, continuous monitoring and assessment (M&A) is a must; the work needs to be conducted by either the scientists themselves and/or by local support staff. In many current research programmes there is lack of resources or even emphasis on M&A. Thus, more investment in training and capacity building is needed for M&A generally, but specifically to improve skills in related knowledge management and decision support. In this context the preservation and improvement of biodiversity is a key challenge. To raise awareness, to lobby and provide evidence for the value and positive impact of improved biodiversity, it is at first necessary to convince decision-makers and the general public of the relevance of this challenge. In the BMBF-SLM programme, experience has been gained in this regard in several research areas where monitoring of biodiversity has been a major activity.

Other monitoring activities, in particular related to water quantity and water quality as a result of land management change, are needed in many world regions. They are required for understanding water abstraction and water quality of rivers, especially regarding salinity of rivers and irrigation waters, water flows and ground water levels (see Chapter 2 Section 2.1 page 50). The complexity of interactions and the severity and speed of the changes are still not well understood.

Examples

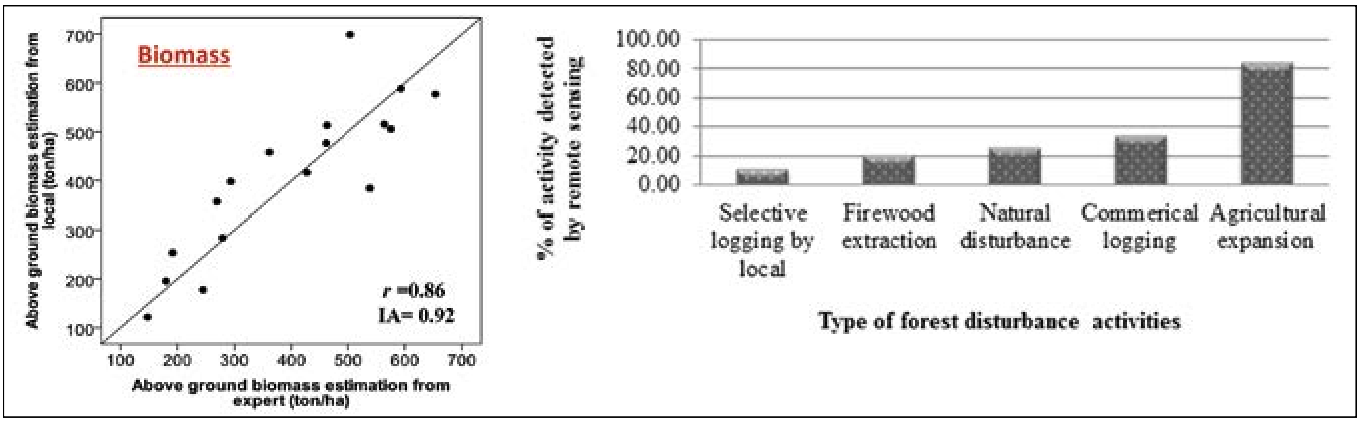
Cooperation with national park and para-ecologists

On the Mahafaly Plateau, para-ecologists have received training on biodiversity monitoring techniques and interview methods. In collaboration with the National Park agency and researchers, they regularly monitored the occurrence/ abundance of key indicator species in the National Park. Since 2006 the University of Hamburg has supported a research camp, from which monitoring activities can be coordinated. The data collected are integrated into a regional database hosted by an environmental NGO and underpin, among other purposes, the development of a long-term biodiversity monitoring programme and a food security alert system. The National Park agency can also use the data for continuous updates on population size and distribution of endangered species (see Approach 'Participatory M&E' page 243). The monitoring programme is envisaged to be an integral part of the future action plan of the National Park agency.

Community-based forest monitoring

Countries and projects participating in a REDD+ mechanism – or any payment for ecosystem services system (PES) – are required to set up a reliable, transparent and credible system of measuring, reporting and verifying (MRV) changes in forest areas and forest carbon stocks. This MRV system relies on well-planned and executed monitoring. Under the framework of REDD+ a case study was carried out in Tra Bui commune, Quang Nam province, Central Vietnam to evaluate Community Based forest Monitoring (CBM) as additional support to the national MRV system for measuring forest above-ground biomass, and reporting forest changes. Local communities have been involved in conducting forest inventory measurements through 'crowd sourcing'. This saves money as well as conferring skills – if properly trained, the level of precision is comparable to that of professional forest inventory staff (Figure 5.16 left), the cost is much lower (1.2 USD/ha, compared to 6.4 USD/ha for national experts). Most importantly, local communities are able to repeat the measurements on a regular basis and remain aware of large and small-scale forest disturbances (Figure 5.16 right), which are rarely captured in national databases or from remote sensing. In addition, interviews with members of the local community provided information on the drivers of deforestation and land use changes, where quantitative assessments are crucial for the design of policies to reduce deforestation.

Figure 5.16: Use of expertice from local communities - Comparison of biomass estimates from local communities and forestry experts (left) and assessment of deforestation drivers according to local communities (right) in Tra Bui, central Vietnam (adapted from Pratihast et al. 2013).



5.3 Framework conditions and governance

Figure 5.15: Dissemination material offered during stakeholder workshops, Brazil. (Marianna Siegmund-Schultze)

For encouraging sustainable land management, favourable framework conditions and supportive governance is essential. This includes suitable institutional, policy and legal frameworks, local participation as well as regional planning (landscape or watershed), capacity building, monitoring and evaluation, and research. An enabling environment aims to optimizing people's access to water and land, access to markets, knowledge, and support (financial and technical). It also targets encouraging and supporting implementation as well as upscaling of SLM good practice. It is a major challenge – and often beyond the scope of implementation-oriented research to contribute to the creation of SLM friendly framework conditions.

A word of caution is necessary here: the mandate of most research projects does not include real world implementation. Research reaches its limits when it comes to incentive structures, power relations, and existing institutional and political frameworks: even though the latter are all of high importance in any implementation-oriented action. Implementation-oriented research can investigate, analyse and describe all this by involving governance and political scientists. It can support stakeholders to deal with challenges related to these frameworks. And it can contribute to transparency and adequate communication with those in power and decision-making positions, by supplying important background information and knowledge, or making suggestions for necessary changes to support SLM implementation.

At this juncture, research needs support from people coming from outside, as knowledge brokers and inovators. This is a role that has not yet been taken up to the extent needed. The role of research, in this case implementation-oriented research, usually ends with supplying unbiased information and providing it in a form that others can access – and act upon. Therefore, research projects would ideally closely cooperate with 'interface managers' such as knowledge brokers and change managers (Böcher and Krott 2012; Defila and Di Guilio 2016). Research could make much more use of such competencies and experts for communication, stakeholder integration and management, and implementation-oriented work. These competences are available and increasing worldwide. But science funding and administration has not taken much note of this so far (e.g. Climate Knowledge Brokers (CKB) Group and Knowledge Brokers Forum (KBF)). Also, institutions can take on the role of interface organisations or intermediaries. Identifying those organisations is a core part of stakeholder analyses and developing contacts in the research region. For science, the existence of such platforms and intermediary organisations are rare but important entry points for their possible contributions to supporting better governance of water and land.

5.3.1 Land and water use rights/ access to natural resources

One key issue for the success of adoption and spread of SLM is land ownership and land and water use rights. Land users often are reluctant to make long-term investments in SLM practices or to implement them when they are not the owners of the land, or do not have long-term secured user rights.

Lack of long-term security hindering innovation

In the Kulunda region of south-west Siberia, at least two aspects of current property rights are of great importance: first, there still exists a high proportion of rented land which reduces land users' motivation to protect and invest in long-term land improvement. However, since the liberalization of the land market in 2003, the proportion of privately owned land has been steadily increasing. Secondly, administrative and institutional weaknesses in public land governance undermine the effective execution of land use rights, and implicitly de-motivate users to invest in land quality improvements. Among the most particularly influential factors are unclear ownership titles, missing borders in the terrain, unfinished registration and authorization of ownership titles, and weak enforcement of soil protection laws. The resulting transaction costs go onto the expense sheet of private land users and owners. Therefore, complete abandonment of private land ownership is not exceptional in this region. This affects, in particular, the implementation of new and expensive land management technologies.

For the adoption of no-till and/or minimum tillage technologies the researchers identified three types of barriers as highly relevant: (i) high investment costs of the conservation technology, (ii) high learning costs of small-scale farmers and high costs of wage labour, and (iii) persistent institutional impediments on the land market, and un-resolved property rights to land. Until land users possess long-term secure ownership rights, and with it long-term control of the land, the interest in such investments remains low. Consequently, property rights directly impact the owner's ability to exercise, ideally with low transaction costs, residual rights of control over his/her assets and consequently receive net income from the land.

5.3.2 Policies, laws and their enforcement

Another challenging issue for taking decisions on land use and land management is policies and laws such as environmental and planning regulatory frameworks as well as subsidy policy (i.e. incentives). The regions investigated in the BMBF-SLM programme display enormous differences when it comes to policies and laws related to land use. There are many obvious shortcomings in regions such as Madagascar or southern Africa, with inadequate means for the enforcement of land ownership and use laws and regulations. But even in a country like Germany with much well-established legislation on land use and land management in place – like the national Kataster (cadaster) registering every single plot of land and its ownership – policies and laws related to land use and management remain a great challenge.

Inefficient law enforcement is a major challenge in many regions. The lack of control and sanctions as well as lack of sensible follow-up activities, were repeatedly identified as being a strong obstacle to more sustainable management of the land. Altogether it seems quite common worldwide to pride oneself in far-reaching laws on more sustainable land management and use and related plans. But too often there is little, or non-existent, implementation and monitoring. Implementation-oriented research can make the existing governance situation transparent and give advice on how legal frameworks can be used, or how they need to be changed to support sustainable land management.

Examples

Assessing suitability of existing legal frameworks

German land and environmental laws are backed up by national and European incentive schemes. They offer a relatively broad spectrum of instruments and regulations supporting the implementation of SLM practices related to climate change adaptation and mitigation (Figure 5.17). However, many shortcomings appear in their execution and implementation.

Figure 5.18 presents the main land use sectors of agriculture, forestry and settlement/ transportation and the formal and informal regulations in each sector, known as hybrid governance-systems:

According to professionals dealing with land use governance at the national level, stakeholders in Germany concentrate on the instruments of the Spatial Planning Act, the Building Code, the Water Framework Directive, the Federal Soil Protection Act and agro-environmental measures. The possible change of land management and use under conditions of climate change is seen mainly in terms of the use, enforcement and coordination of these instruments. Information on modification and supplementary needs on how to deal with climatic change is seen as less important.

Identifying gaps in the use of instruments and governance

The aim of land protection in Russia is to prevent and eliminate pollution, degradation and damage to the land and soil, and the restoration of soil fertility. Agricultural land protection is regulated via more than 20 laws and related by-laws that specify control, and how state agencies such as the Administration of Natural Resources and Environmental Protection have to implement them. The implementation of agricultural land protection policy relies on traditional 'command-and-control' systems. Actors who are found to have broken the rules are penalized with heavy fines, losing existing contracts with the state authorities or even faced with land expropriation. On the other hand, positive motivation via economic incentives or respective advisory programmes are not in place. The openness to new approaches and self-organisation therefore is not very high.

Despite the existing regulations and their enforcement, environmental rules and mechanisms have insufficiently contributed to land protection objectives. This becomes clear with the example of Russian rules aiming to prevent land abandonment. These rules specify penalties for stopping cultivation of the land. Land abandonment, that is withdrawal from land use and production of goods, however, is usually caused by economic reasons. Prosecution, therefore, seems not necessarily a sensible response. Also, in the case of prohibiting the burning of crop residues, existing laws were not on target. Here it was difficult to prove who (land users? passers-by?) was responsible for violations of the law, and who should be prosecuted. State controllers admitted that in the majority of cases, they had no clear evidence about the offender. Therefore, without appropriate changes in related governance mechanisms (those who ensure that the laws are being followed) and the chosen instruments of implementation, a policy for mitigation of agricultural land degradation can hardly be effective.

As a first step this 'gap' between the challenges at hand and the implementation of instruments must be identified, and regional stakeholders need to get involved in order to find out more about possible ways forward. In particular the economic interests of the local land users should be taken into account. And based on that: what could be well suited regulative instruments that respect local land users' economic, social and cultural interests? What are effective 'incentive-based' instruments for agro-environmental policies? This is a challenge, of course, especially for countries like Russia and China with top-down governance structures. But experience shows that rules and regulations that make sense to all involved on local and regional levels are effective for sensible reforms towards sustainable land management and use.

Figure 5.17: Existing multiple types of instruments for sustainable land management in different political sectors and at all administrative scales in Germany (Grabski-Kieron and Raabe 2015).

€	Incentives and Subsidies	*for example…* – Common Agricultural Policy (direct payments, greening, agri-environmental measures) – Joint Task for the Improvement of Agricultural Structure and Coastal Protection – urban development funding – innovative funding models (e.g. MoorFutures)
i	Information and Consulting	*for example…* – fertilization advice – forest management advices – calculation of consequential costs of infrastructure – brown field monitoring
§	Juridical regulations	*for example…* – plight for forest preservation – juridical prohibition for ploughing up of grassland – impact mitigation regulation – environmental assessments
	Cooperation	*for example…* – agriculture and local water suppliers (fertilization) – intercommunal cooperation – forestral associations – public private partnerships
↖↑↗	Spatial planning	*for example…* – spatial planning (e.g. regional planning, urban development planning) – sectoral spatial planning (e.g. landscape planning, traffic planning) – urban and neighborhood-based planning – land consolidation
€ / §	Economic and fiscal instruments	*for example…* – fiscal equalization scheme – commuting allowance – emissions trading – area trade (perspectively)

5.3.3 Improve incentives and support

As many other challenges with long-term effects, for example climatic change and biodiversity loss, sustainable land management suffers from trade-offs between short-term economic interests, and long-term conservation and improvement of water and soil. For the individual farmer, rapid economic interests are imperative: they need to feed their families, survive on the agri-business they run, and they are often not rewarded in any other way. The fruits of more sustainable measures of farming can only be harvested in the long-run. To set incentives, of one form or another, for long-term investments in sustainable land management therefore is a key task of public funders of states and/or international organisations. Compensation needs to be available in cases of, for example taking land out of agricultural use for the benefits of biodiversity protection and/or climate change mitigation and adaptation. Related examples of those practices are described in Chapters 3 (page 79) and Chapters 4 (page 96). But the implementation of any kind of sustainable land management practice usually needs incentives and support – which is often not yet in place.

Examples

Incentives for efficient water use

In the Brazilian São Francisco Basin, especially in the Itaparica reservoir region, farmers in public irrigation schemes that had been established as compensation for compulsory relocation are receiving few incentives for more environment-friendly ways of farming. Since water and electricity for pumping are still free, and the provided irrigation infrastructure not fully adequate, farmers use as much water as they think is useful for their purposes. In a test run, simulated invoices for water use were sent to farmers. This is the first step to planned water pricing as it is common in other regions and is stimulating some farmers already to rethink irrigation practices (see Chapter 1 page 34).

Supporting investments

For many rural farmers in the Okavango Basin, the capacity to invest in improvements to farming practice is very limited. Financial means for investments, for example in farming technology, is often not available. Additional support measures for the agricultural sector are strongly recommended for improvements of yields and income.

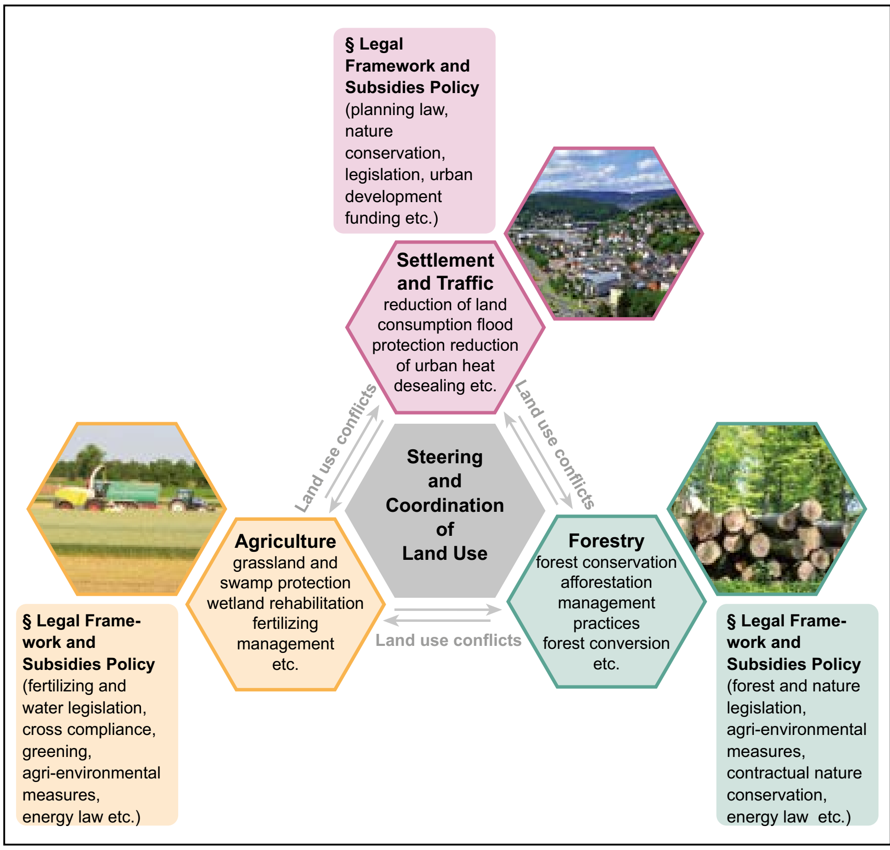


Figure 5.18: Land use governance - Formal and informal regulations regarding climate change, Germany (Grabski-Kieron and Raabe 2015).

Distribution of financial means

In the Kulunda steppe region of Russia, the design of agricultural or environmental policy and concrete measures, often suffers from insufficient interaction with local communities and regional-based stakeholders. Social, demographic and economic challenges vary strongly over the predominantly rural Kulunda region. Yet, agricultural and rural development policy is mostly designed at federal level. More specific problem-oriented local solutions are often not possible. The dominance of the federal system is illustrated when looking at available budgets: regional agriculture expenditures and investments amount to just 16% of the overall budgets (Agricultural Development of Altai Krai in 2013 – 2020, Ministry of Agriculture 2015). In effect this means that for local and regional initiatives there is usually no way of funding. They have to comply with what is decided within the federal framework. Implementing measures of SLM in the region would need additional support, or a change in distribution of budget and decision-making.

5.3.4 Empowerment and strengthening cross-cutting institutions

Setting incentives and supporting land user and their organisations effectively needs powerful institutions. Developing more effective laws requires appreciation of the diversity of policy mechanisms and institutional service providers and the acknowledgement of interactions between different rules and laws. This is especially the case when it comes to cross-sectoral and larger-scale management coordination in river basins. They are important users of research results and ideal intermediary organisations between research and implementation. However, in their focus on a broader spectrum of sectoral policies those institutions need strengthening and empowerment to adequately fulfil their role.

Examples

International cooperation for the Okavango

The Okavango River Basin Water Commission (OKACOM) advises the three riparian states, Angola, Botswana and Namibia, about the optimal use of the river's natural resources. The commission has an important function, as the Okavango River plays a key role regarding water distribution in the three connected states within a problematic upstream–downstream context. However, to be effective the transnational nature of OKACOM needs to be respected by national policy bodies. The commission needs a stronger political mandate and long-term public funding to fulfil a meaningful advisory role, to promote coordinated and environmentally sustainable regional water-resources management, and development, and to have the means to support and facilitate implementation, monitoring and control of suggested policy measures.

Cross-scale River Basin Commission

For the São Francisco River Basin, the longest river running entirely within Brazilian territory, a management committee (CBHSF) was created by presidential decree in 2001. The overall objective of the committee is good governance for sustainable water and land management. The committee intends to coordinate water policy at federal level with the riparian states (Minas Gerais, Goiás, Distrito Federal, Bahia, Pernambuco, Sergipe, and Alagoas) as well as action at municipal level. The guiding paradigm is multiple water use, and the support and balancing of demands from people's livelihoods, energy generation, and sustaining ecosystems.

At meetings of the CBHSF, participants gather to promote the 'revitalization' (restoration) of the degraded areas in the watershed. Objectives of the regular meetings are to discuss ways and means to achieve full protection of the springs and control of erosion. This should effectively contribute to increase, or at least stabilize quantity and quality of, water flows. Participants also develop plans for renovating streets and improved drainage in order to reduce silting of the water bodies, and for adopting more efficient soil conservation measures. Selected measures have a demonstrative character and also are intended to promote environmental awareness. Citizens in the riparian states may suggest new projects which are discussed and decided in regional, technical, and public sessions. The CBHSF, through its executive agency AGB Peixe Vivo, issues public calls for tenders.

This scope of work makes the CBHSF an ideal partner and intermediary for implementation-oriented research. But after fifteen years of its existence, achievements of the CBHSF are mixed. The committee does not have a strong enough mandate to prevent big economic and policy players such as the hydroelectric and other public companies – which are strongly linked to the federal government and its agencies – to pursue their own decision-making processes. But it is an important platform for giving all interest groups a voice, including the regional governments, science, industry, sanitation, smallholders and commercial farmer groups, fishermens' associations, and indigenous people living along (and from) the river. To feed research results into this forum a first scientific conference organized by the committee and scientists working in the watershed took place in 2016.

5.4 Use of Knowledge

5.4.1 Joint target setting/ co-design of research questions and objectives

Filling knowledge-gaps is the traditional role of scientists and is usually very welcome. However, commonly it is not the knowledge gap of the land user or of the person working in the regional water authority that initiates the process of setting research into action. It is the knowledge gaps and interests of the scientists themselves which they have pre-formulated – usually long before a first meeting with stakeholders. This, then, is the first great challenge regarding implementation-oriented research: meeting up with those who have requirements that need to be researched. To set up demand-driven and implementation-oriented research, meetings need to take place as early as possible in the overall process of setting up a project and/or research programme. During such early stage meetings implementation-oriented research objectives should be jointly identified. On this basis information, and knowledge, can be produced that are tailored for awareness-raising about the roots of problems. Such knowledge then is the basis for evidence-based decision support, adaptation and fine-tuning of innovations and selected measures for more sustainable land management.

Identification of knowledge gaps
Identification of knowledge gaps in a transdisciplinary context therefore starts with the needs and demands of end users – whether land users, other implementers, planners and local/ regional decision-makers. Various users may profit from research and learn about improved or innovative ways of land management. For that, they need to put their own experience into a wider context. Last but not least, the cooperation with the scientists may contribute to improving the ability to overcome, step-by-step, present conflicts of interest between different expectations towards management of the land: for example the potential conflicts between productivity, environmental protection and renewable energy.

Much knowledge about land management has been produced during recent decades but it often proves to be sparse on specific themes, incomplete, or of low quality when it comes to implementation in specific contexts. For example, in some regions different governmental organizations – at federal and state levels - are gathering data on water quantity and quality and some are publishing them on their websites. However, datasets are often incomplete, not comparable, poorly organized, or remain inaccessible (thus effectively secret). Consequently, water users and other stakeholders barely know the status of their land and water resources. Where monitoring is almost absent, the efficiency of different practices within a landscape is not known (e.g. the effect of buffer strips along water bodies). And finally at the plot scale, land users may lack specialized knowledge, for instance, about pests and diseases of their crops and safe use of 'agricides' – or biological alternatives. These are gaps that can be readily identified by asking those who are involved, hands on, in land management.

5.4.2 Knowledge management

That knowledge is not broadly shared within and among sectors, disciplines and stakeholders hinders evidence-based decision-making and hence development of sustainable land management practices and dissemination of specific innovations. Sectoral knowledge is often well-developed and focussed on working solutions within individual groups of the overall 'actors landscape' of SLM. But this knowledge, often enough, is not sufficiently shared and integrated into broader alliances for sustainable land management.

Generally speaking, a wealth of knowledge is available on how SLM technologies and approaches work, where they are applied, what impact they have – as well as implementation aspects. Yet, this knowledge is often scattered and not well accessible. For example there is considerable knowledge about the effects of deep ploughing on land use productivity and on loss of water and soil as compared to minimum soil disturbance techniques. This is true also for the hazards of conventional pesticides, compared to the benefits of biological pest control, in relation to water pollution and quality – as well as to human and animal health. Appropriate knowledge management helps to provide access to information where and when it is needed.

Examples

Compiling information in one place
In the Mahafaly region of Madagascar most of the compiled information on past and current projects is not available through modern library services. This is especially true for most of the so-called 'grey literature', which are reports by NGOs or GOs, regional studies and surveys or monographs. As a result, many projects start out from scratch and are unaware of the existing knowledge and activities. There can also be 'institutional amnesia' where agencies are not even aware of what they, themselves, have carried out in the past. Thus valuable lessons are lost. In response to these problems, a regional data monitoring and service centre based in the provincial capital, was established to compile data collected by current and past projects, and to make them available upon request. This proved to be useful for all stakeholders who regularly carry out research or development projects in the region, including both GOs and NGOs.

Developing a knowledge management system
However, there is a considerable challenge involved: for knowledge to be accessible to people in the region like farmer extension workers or people working in local administrations, it needs to be documented in a way that it can be easily retrieved, and made available. Continuously keeping this information up-to-date, proper management and provision of access for the exchange of knowledge, and last but not least, for making knowledge accessible and useful for decision-making requires sustained commitment and support.

Some steps in this direction have been taken for land, and especially water, management in Vietnam. The River Basin Information System (RBIS) of the Vu Gia Thu Bon River Basin (VGTB), provides a useful service for the region. The RBIS basically is a knowledge management system. It has been initiated and designed

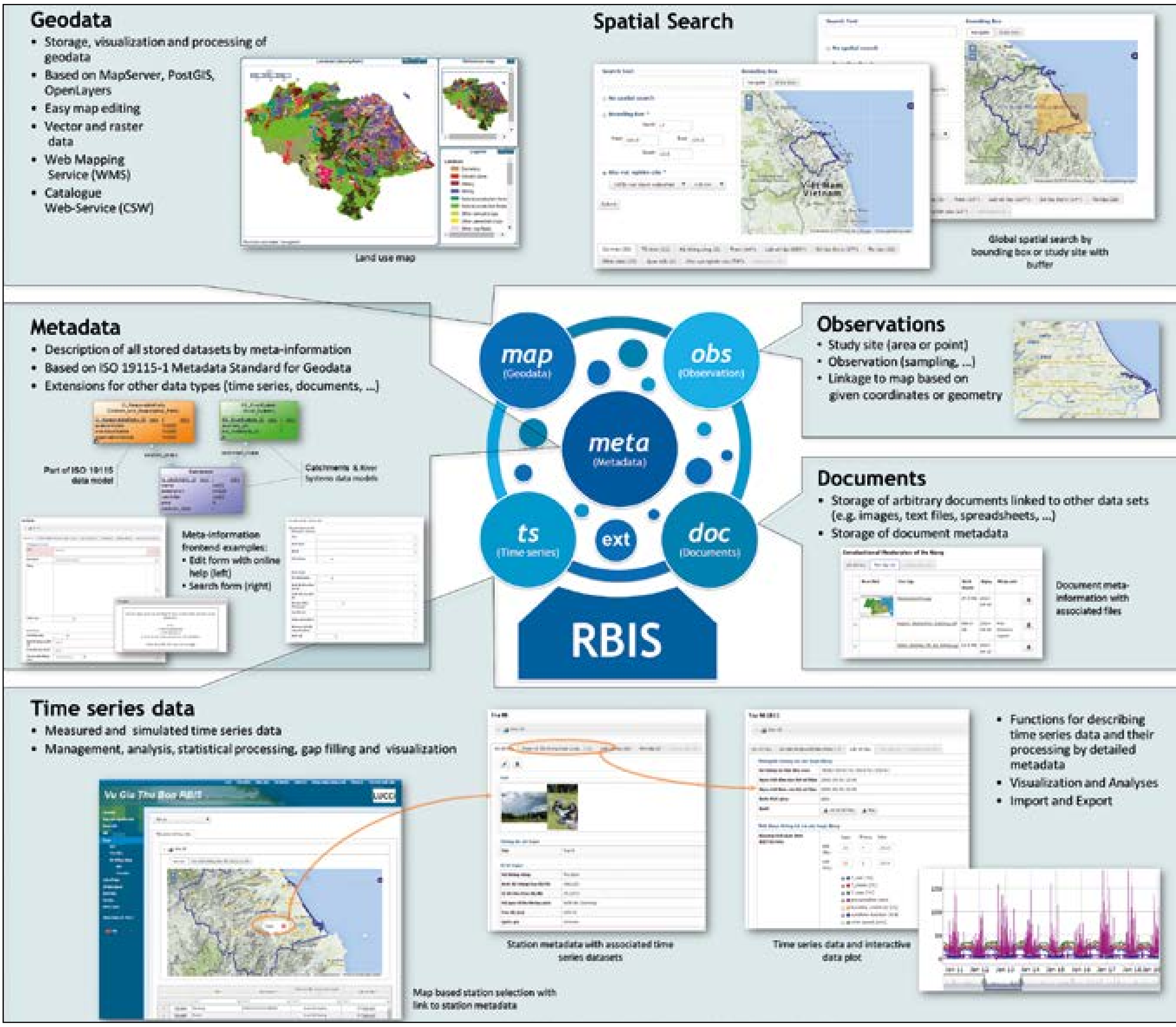


Figure 5.19: Knowledge management for VGTB River Basin - Structure and main modules of the River Basin Information System (VGTB RBIS), Vietnam. (LUCCi project: http://leutra.geogr.uni-jena.de/vgtbRBIS)

to organize, evaluate and share knowledge as well as for access and use of its data as a basis for evidence-based planning and decision-support. As such, it links research to practice. For example: sufficient, effective and sustainable water and land resource management at river basin scale can only be achieved if it is based on robust and reliable data and well processed information, which can be shared with a broad group of relevant stakeholders, researchers, decision-makers, and land and water users. For this purpose a comprehensive open-source database and information management platform is a suitable tool.

Figure 5.19 illustrates the general functions of this approach. The VGTB-RBIS serves as a comprehensive information system and decision support instrument for all stakeholders, including decision-makers and researchers. It stores, manages, analyses, visualizes, and links different types of data in the context of multidisciplinary environmental assessment and planning, e.g. data related to climate, soil, land use, water resources, socioeconomic modelling, or scenario results. Principally the information transfer between researchers and decision-makers concerns land and water management data as well as elaborations for decision-makers in the form of reports, interpretation, and analysis.

From knowledge management to possible action there still is a long road to travel. Researchers active in Vietnam have taken on the challenge and have been contributing to building up a 'knowledge-to-action-community'. The various activities involved are illustrated in Figure 5.20.

Knowledge also needs a location: the RBIS platform is hosted by the VGTB River Basin Information Centre (RBIC) in Da Nang. The centre can be accessed by all land management stakeholders of the region (see Approach 'VGTB information centre' page 275). Staff recruited from the local university explain the RBIS tool (Figure 5.21). In this way the centre also offers decision support.

5.4.3 Knowledge exchange: transfer and sharing

Knowledge exchange and transfer can take many forms. It includes methods such as workshops and seminars around specific themes at different levels of decision-making, exposure visits, demonstration plots and – if possible – close cooperation of researchers from different disciplines with local supporters and carriers of knowledge. Methods and content of those activities have to fit the level of communication – whether village, municipality, regional, national – and the interests of the respective stakeholders. At local level, for instance, existing farming innovations within the livestock sector were discussed, whereas at river basin level, the topics were participatory governance and water modeling to inform decision-makers. Approaches described under 'awareness

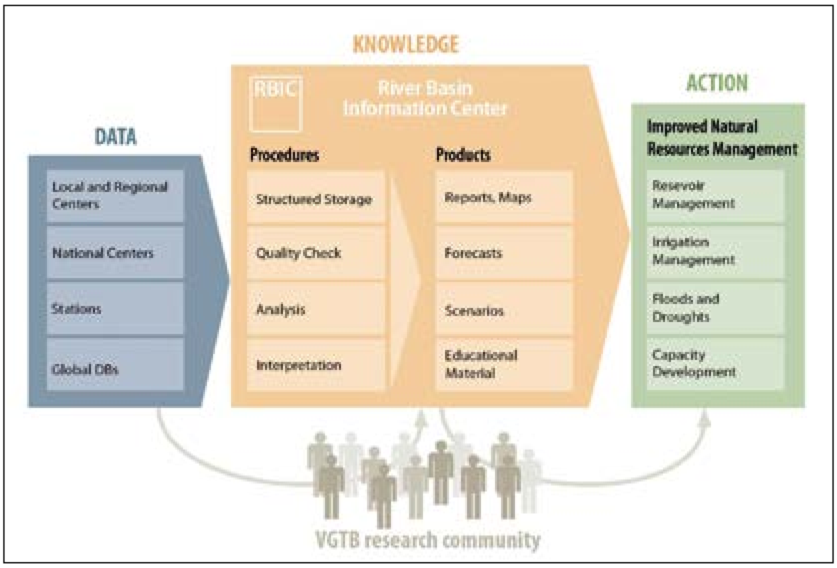


Figure 5.20: Supporting the process from data collection to possible action, Vietnam. (LUCCi project)

raising' (see page 104) can also be used for knowledge exchange and transfer. It is an important aspect in several of the activities illustrated in this chapter.

Field days with multiple impacts

In Campo Verde Mato Grosso, Brazil on-farm field experiments and research combined with field days and exchange visits proved to be promising methods to spread new sustainable land management practices in the Amazon, not only for smallholders but also for large-scale farm managers. On-farm experiments were successfully used to support the understanding of potential new farming methods. Surprisingly, however, they proved to be not only useful in that respect: ensuing discussions with the land users and regional land management authorities showed that making things more concrete 'on the ground' opened the way for better understanding of 'higher level' challenges to present day farming such as those resulting from climate change and world trade.

5.4.4 Integrating knowledge for decision-making

Decision-making goes beyond the realm of science and research. It involves the local, regional and federal polity; that is a vast group of people working in governmental institutions and ministries, right up to members of governments. Access to them is normally difficult for scientists. However, implementation-oriented research needs to include decision-making into the overall perspective of what can be done with its results.

Figure 5.21: VGTB-River Basin Information System explained to regional stakeholders, March 2014, Da Nang, Vietnam. (LUCCi project)

For sustainable land management, a common problem has to do with vested interests and the routes and directions of decision-making: in many countries decisions on land use and land management are often hierarchical in nature rather than participatory. Thus top-down rather than bottom-up. Land users consequently have to accept the decisions made in upper administrative levels.

In addition to top-down decision-making, different ministries or provincial departments of the ministries seldom talk with each other. There is lack of cooperation among governmental agencies and local administrators. Their structure and orientation can be a hindrance when it comes to developing synergies, and taking interdependencies across different aspects of land management into account. Yet, it is their responsibility to make their plans understandable and transparent to all stakeholders, as well as to think in a broad perspective – including economic, social and environmental aspects – about possible negative effects and repercussions of different land uses.

There are two approaches researchers can adopt to answer to those challenges. One is making research results available in a form that is accessible to administrators and stakeholders while integrating all aspects of land management in one system. This is often done with model-based decision support systems. Another approach is to engage all relevant stakeholders in a process of joint scenario development, exploring options for future developments as a basis for future decision-making. The two following examples illustrate those approaches.

Examples

Decision support systems (DSS)

To support better cross sector coordination in the Tarim River Basin in China, a Decision Support System was developed in close cooperation between the German and the Chinese project partners. To ensure ownership of the DSS, relevant stakeholders from the Chinese authorities were involved in the development of an open source freeware. The DSS is freely available to all who want to use it (Figure 5.22). This, for many Chinese authorities, was new and an unusual approach in the development of a planning tool.

In general DSS as a planning tool often suffers from insufficient involvement of the end users. With the exception of some good examples (including the one described above) stakeholders are often involved far too late in the process. The decision to research and produce a DSS is commonly taken long before the involvement of those who will use it.

When it comes to the role of offering decision support, scientists are well-advised to check with those who could potentially use such tools from the outset. That is, a working DSS needs to be co-initiated and co-designed from day one with the eventual users in farming, water management, or other areas. Only then can a DSS make a sensible contribution to decision-making. And only then is there a chance of the DSS being sustained post-project. Otherwise the DSS developed doesn't 'fit' the real planning needs and schemes of those working in practice. And there is an important sense of ownership involved: if stakeholders are invited to say what they need and to help with co-designing a suitable tool, the chances are much greater that they will be eager to test it, further shape it to their practical challenges, and in the end genuinely make use of it.

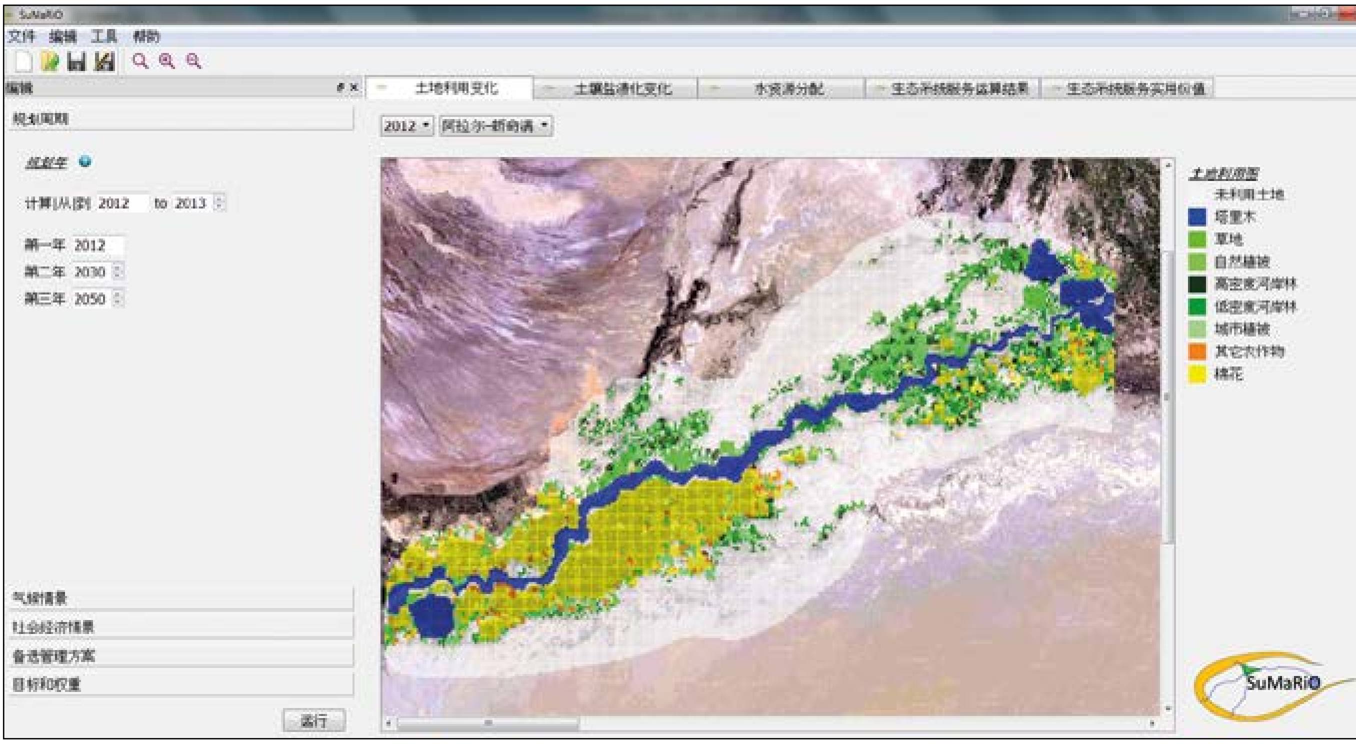


Figure 5.22: Interactive land use map as planning tool - Graphical User Interface of the DSS in Chinese language, showing the interactive land use map and the corresponding land use types on the right, which can be modified with a user-friendly interface (Disse 2016).

Jointly developing story lines for the future

The BR-163 highway belongs to the 'Deforestation Arc' on the southern border of the Amazon rainforest. The highway runs from the semi-humid tropical savannah in Central Mato Grosso to the humid tropical rainforest in the north (Figure 5.23). It covers one of Brazil's most rapidly changing regions.

To explore how land use in this region will develop over the next 30 years and how it will be affected by the implementation of different land use options, a set of scenarios were developed that portray different plausible development pathways. A panel of experts translated the findings of several stakeholder/scenario workshops and extensive stakeholder and expert interviews into narratives of 'storylines'. These storylines were used to further define the scenarios, but also acted as an independent form of communication. In a last step, the 'qualitative information' derived from these storylines was quantified so that it could be fed into computer-based models and further analysed in scenario simulations (for illustration and a more detailed description of the development process of the story lines (see Approach 'From storylines to scenarios' page 163).

Each of the four storylines comprises a title and a short narrative of the respective 'future world'.

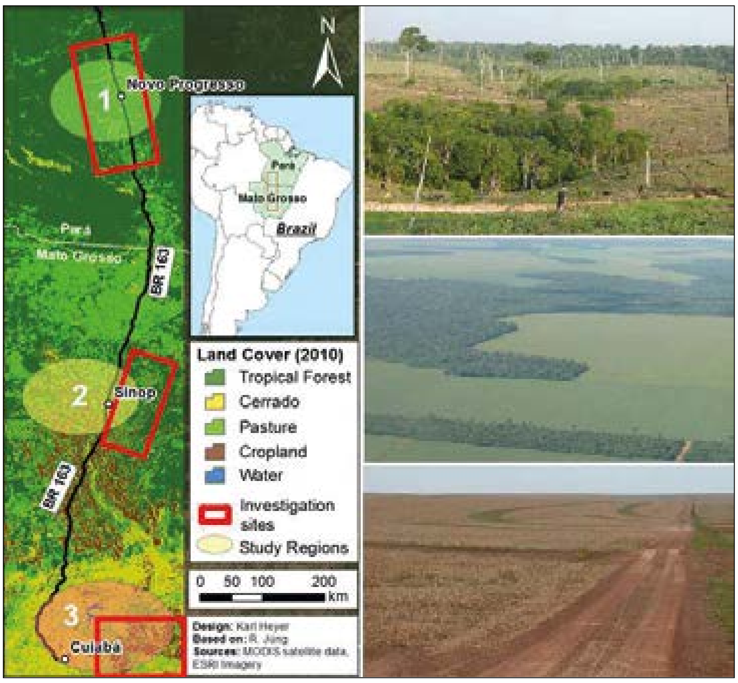
Business-as-usual: Current trend extrapolation of global demand for Brazilian agro-products, continuous conversion of natural ecosystems, intensification of agriculture, focus on cattle and soybean.

Sustainable development: Participation, citizenship, law-enforcement, inclusive of economy, food sovereignty, protection of resources, increasing demand for certified agro-products, diversity of agro-production, regional identity, clarification of land titles, increasing livelihood and prosperity.

Legal intensification: Increasing global demand for Brazilian agro-products, no further conversion of natural ecosystems, intensification and specialization of agriculture (for the Asian market), law enforcement and legal security, decreasing birth rate, increasing livelihood and prosperity.

Illegal intensification: Increasing global demand for Brazilian agro-products, continuous conversion of natural ecosystems, intensification of industrial agriculture, no significant law enforcement, small-scale farmers continue migrating, increasing crime rate.

Figure 5.23: Map of the sub-regions along the highway (left). Photos on the right: top deforestation front moving into the rainforest, middle: intensive soybean production 30 years after conversion, mixed with still-intact remnant islands of rainforest, bottom: former *Cerrado* now intensive agricultural production 50 years after conversion. (Carbiocial)



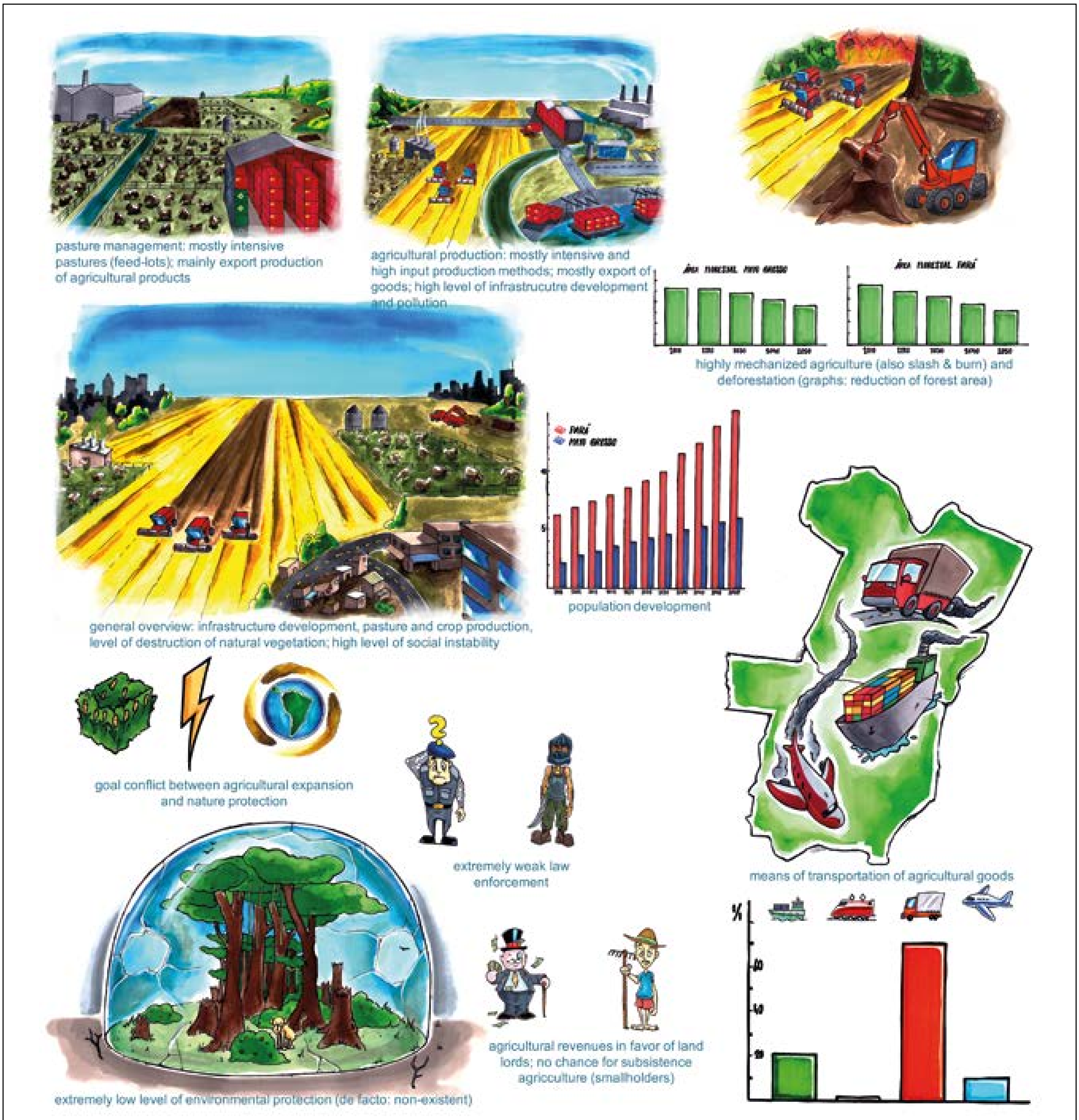


Figure 5.24: Storyline 'Illegal intensification', Brazil. (Jan Göpel, Copyright CESR)

In addition they are represented by posters to visualize the most important aspects of each 'story' for stakeholders and the interested public (Figures 5.24 and 5.25).

The scenarios were presented to inform local people and authorities about the consequences of their current activities for the future. Thus, all stakeholders, from smallholders to the responsible politician, could see the potential outcome of current land use as well as being able to 'interpret' the very different scenarios as options from which they could choose. With the help of the storylines and the scenarios they could 'look' into possible future development of their community, better understand possible effects on the entire Amazon and impacts on the world climate, as well as learn about sustainable (or unsustainable) development pathways for their region.

5.5. Stakeholder integration/ co-production of knowledge

To place people and supportive institutions at the centre of land management and development processes, an integrated multi-stakeholder approach was developed some 25 years ago in the aftermath of the 1992 Rio Conference on Environment and Development (Hemmati 2002). For research, this meant not only a multidisciplinary approach across all involved scientific disciplines, but a transdisciplinary approach, where potential practical users of the research results are included throughout the whole development process of the research project. This means that end-use stakeholders need to be included in the set-up of the project (*co-creation and co-design*), actively involved in the process of conducting the research work (*co-production*), and installed, ideally as lead partners, for communication and dissemination of results (*co-dissemination*).

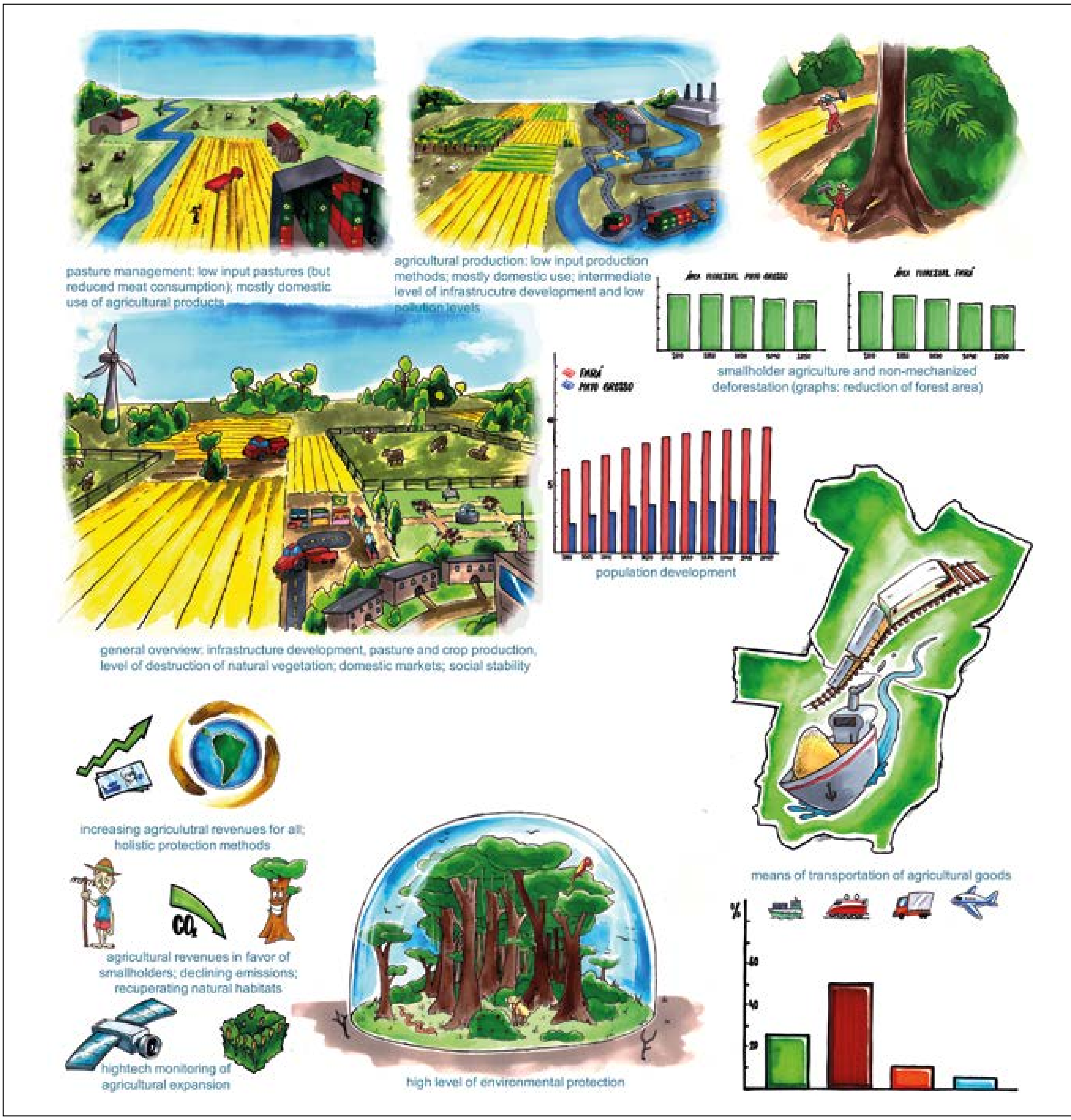


Figure 5.25: Storyline 'Sustainable development', Brazil. (Jan Göpel, Copyright CESR)

However, to this day, each of these facets of transdisciplinary work have proved to be very challenging for research funders and scientists themselves. It is not only that perspectives among and between scientists and possible users of research, such as politicians, planners, or local land users differ significantly, but the research and science systems themselves are slow in accepting the challenges involved and perceiving genuine gains. Here comes into play an important (and new) role for science funders – who need to set suitable framework conditions of time, flexibility for usage of funds, and initiate new incentives for careers in science communication and science management. Far too little headway has been made to address these challenges (Defila and Di Guilio 2016).

In the present case of the BMBF-SLM programme, it was found to be a major challenge even to maintain a constant and sensible exchange between researchers and the local land users. It was hoped that on such a basis the development of implementation-related land use alternatives would be possible – options that would match people's livelihood requirements and cultural background. However this goal often appeared to be in conflict with the environmental sustainability objectives promoted by the scientists. It has to be concluded that involving the multiplicity of interests of all stakeholders (including science itself) has been, and will remain, a great challenge.

This also concerns the application into existing research programmes of new tools and methods for stakeholder communication and involvement. Here, a continuous exchange between scientists from different disciplines about the merits of various options could be of great use. All this should lead to the establishment of a long-term vision – during and beyond the timeframe of a particular project or programme – with clear pathways that can be set out with the support of a transdisciplinary project. With that achieved, cooperation between scientists and local stakeholders will be easier and more enjoyable.

Figure 5.26: A local 'Forum for Integrated Research and Resource Management' (FIRM) at work, Okavango Basin. (Laura Schmidt)

5.5.1 Adapted and improved participatory approaches

Under these difficult framework conditions it is sometimes surprising what can still be achieved. Here some examples from the work of the BMBF-SLM programme.

Integrated research and resource management

In the Okavango Basin, a stakeholder participation strategy based on a mix of instruments was developed. On the local scale, 'Fora for Integrated Research and Resource Management' (FIRMs) were employed to support community-based organizations and stakeholder engagement. FIRMs are established in a participatory manner, putting the local community at the centre of their own development (Figure 5.26). They are information platforms that consist of elected community members who meet regularly and initiate a series of development actions involving all service providers needed and involved in the solution of local level resource management challenges. Service providers may be, for example, traditional authorities, government extension services, NGOs, as well as the scientific community (for further information: Kruger et al. 2003).

Figure 5.28: Madagascan Rapid and Participatory Rural Appraisal (MARP) local community setting priorities. (J. Hammer)

Community liaison agents/ para-ecologists

To collaborate with local rural communities and foster communication between researchers and local stakeholders in the Mahafaly plateau in south-western Madagascar para-ecologists were employed. They acted as agents and 'multipliers' of ideas and provided a communication and cultural link between scientists and rural communities. As most of the agents will continue to live in the region, the experiences and knowledge they gained in the project will continue to influence the people around them in the long-term (Figure 5.27). Community workshops were organized in order to integrate local people's perspectives, experiences and knowledge into the research and implementation process (Figure 5.28). The workshops were of different types. The aim of the first type was to establish communication between local communities and researchers about local people's lifestyles. German and Malagasy researchers learned participatory data collection techniques, which were then applied in the field for baseline surveys (see Approach 'Participatory rural appraisal' page 239). The second type of workshops aimed at integration of local livelihood strategies into the modelling process. Participatory games (Figure 5.29) were designed to foster both scientific knowledge production and stakeholder dialogue in natural resource management, conciliate resource conflicts and enable participatory land use planning (see Approach 'Role-playing games' page 231 and Video). Local people simulated their livelihood strategies on satellite maps of their village.

Figure 5.27: Assistants (para-ecologists) getting the SuLaMa project certificate, Madagascar (left). (Jacques Rakotondranary)

Figure 5.29: Livestock keepers simulate their grazing grounds and routes in a role-playing game, Madagascar (right). (Jacques Rakotondranary)

Figure 5.30: The Vice Chairmen of the Peoples´ Committees of Quang Nam and Da Nang opens the final workshop on project research results, March 2015, Vietnam. (Nguyen Tung Phong)

Figure 5.31: Maps, figures, flyers and posters in Vietnamese language presented at final workshop, March 2015, Vietnam. (To Viet Thang)

5.5.2 Multi-stakeholder, multi-sectoral and transdisciplinary approaches

Integrated approaches in science and research imply a shift from the former 'dissemination of results' or 'transfer of technology' paradigms with unidimensional communication (typically at end of projects only: telling others what the scientists have found out) towards involving, listening to problems and ideas, as well as continuously taking in practical knowledge from stakeholders such as extension agents and land users ('participatory research and extension'). The objective of the latter approach is to contribute to solving land users' problems and taking the opportunity to make use of local resources, personnel, and available infrastructures. This – ideally – should happen, and an adequate budget should be reserved for such activities. However, it is possible also to achieve at low-cost. The examples below demonstrate how those stakeholder interactions need to be based on a thorough analysis of the 'stakeholder landscape' in the region.

Examples

Bringing sectors together

In Germany, cross-sectoral discussion platforms on SLM were established involving all relevant land use sectors (agriculture, forestry, settlement/ transportation) (see Approach 'Dialogue platform' page 211) or all relevant actors in a region (see Approach 'Stakeholder participation' page 223). At these meetings, requirements and claims on land use – that is agricultural production, bioenergy, nature protection – were addressed. Possible developments of land use, land use change and different land use management measures were shown and discussed. The aim was to involve all relevant stakeholders and their claims, including end users at regional level and professional representatives on the federal level in a dialogue process which leads to better understanding of land management and sustainable solutions. Involvement of end users from the very outset of the project was intended to increase the chance that recommendations and results would be implemented locally.

Multi-level consultations

In the Vu Gia Thu Bon (VGTB) basin, Vietnam, research activities were conducted in close cooperation with key stakeholders and decision-makers at national, provincial and district levels. Before the project started, and in the first phase, a comprehensive stakeholder analysis was carried out (Who is doing what? Who should we talk to? Which institutions are relevant for possible implementation of results?). A stakeholder matrix was designed. Relevant land use planning documents, developed by Vietnamese ministries and environmental government and non-governmental institutions, were acquired and translated into English for project partners. Annual stakeholder workshops, visits to the relevant institutions (several times a year); interviews regarding current and future development, information demand surveys, stakeholder feedback loops and multi-level consultations were conducted (Figures 5.30 and 5.31), all in preparation for the development process of a River Basin Information Centre (RBIC). As a scientific organization the VGTB RBIC has the advantages of impartiality, a detailed knowledge base and a broad interdisciplinary perspective (see Approach 'VGTB information centre' page 275).

Last, but not least, postgraduate training courses on project results and VGTB related topics were conducted regularly (Figure 5.32).

Constellation Analysis and Bayesian Networks

In the São Francisco River Basin inter- and transdisciplinary approaches of Constellation Analysis and Bayesian Networks ('belief networks': respectively graphical models on relationships among variables of interests) were applied to integrate knowledge across disciplines to support decision-making. Both are 'bridging tools' for bringing together different land management stakeholders as well as scientists from different disciplines to discuss their perceptions and to reach a more common understanding.

Constellation Analysis was used as a tool to clarify positions and interests of human actors/ stakeholders, as well as the roles of natural, technical and regulatory aspects. Such analysis can support

Figure 5.32: Training course in Da Nang, Vietnam on 'Monitoring, Information and Modelling for River Basin Management', March 2014. (LUCCi project)

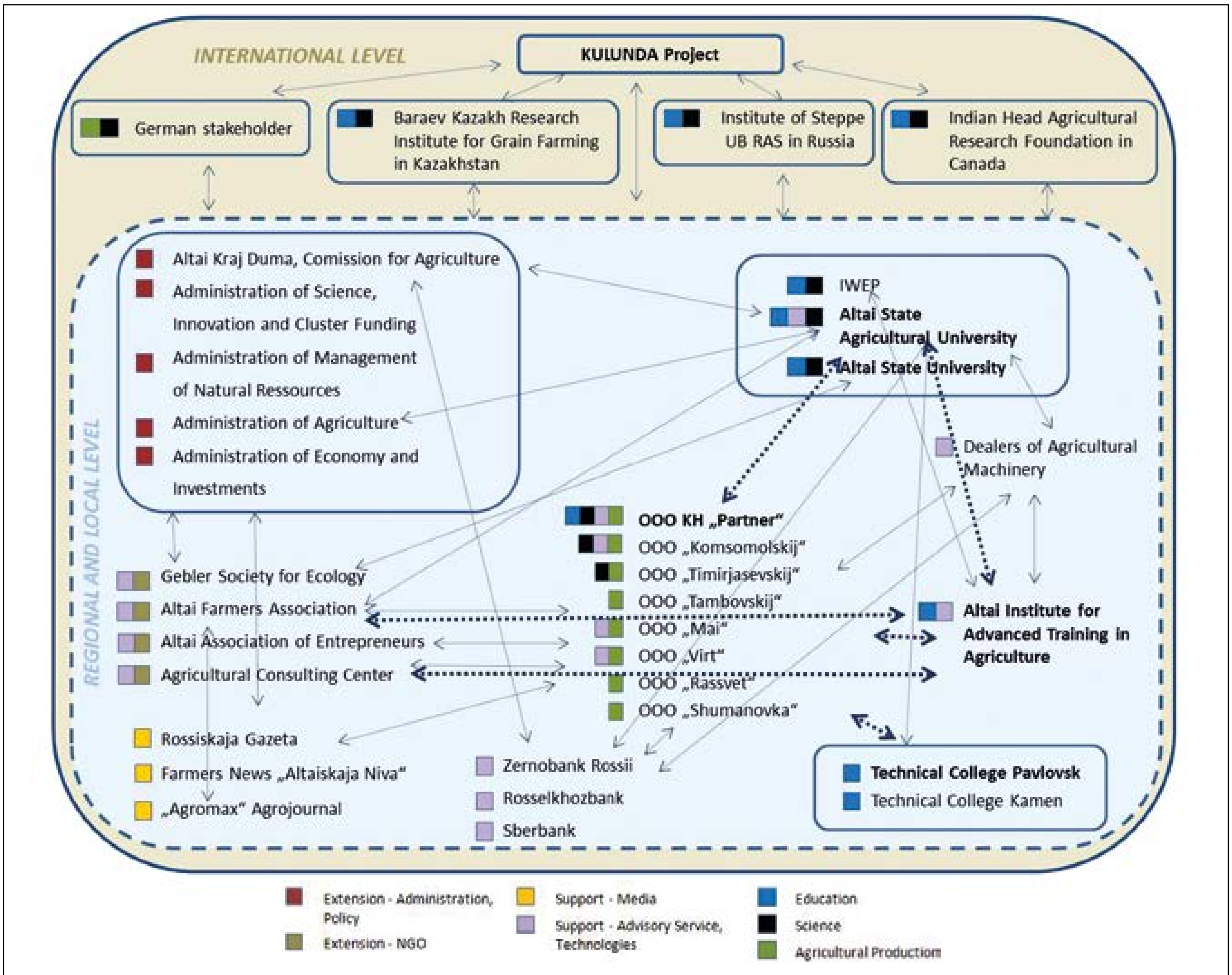


Figure 5.33: Stakeholder network at national/ international level in the Kulunda steppe, Russia. (Peter Liebelt)

consensus-building between divergent positions, help pave the way for better informed decision-making, and support negotiations about land management, possible changes and measures. The main problems addressed by the Constellation Analysis in the São Francisco basin were governance challenges and conflicts related to land and water resources (see Approach 'Constellation Analysis' page 175 and Video). Framework conditions for adopting tested innovations were analysed. Users commented that the method uncovered existing knowledge and perceptions, making them more transparent and usable.

Bayesian Networks on the other hand deal with probabilities and conditions for adopting innovations such as *umbuzeiro* (Spondias tuberosa) tree planting and multiplication. The method starts with a hierarchical model of influencing factors (called nodes), arriving at one or more final objectives; for instance, environmental health and sustainable livelihoods – mediated via the adoption of *umbuzeiro* tree planting (see Approach 'Bayesian Network approach' page 179).

Regional communication platform

To address the issue of missing coordination and communication amongst stakeholders active in the Mahafaly Plateau of south-west Madagascar, a regional communication platform was revived with the support of an international organization with a long-term mandate in the region (in this case WWF). This communication platform helped to integrate the multitudes of SLM approaches and technologies developed by key actors of the region in the many conservation and development aid programmes working in parallel on the Mahafaly Plateau. Better communication among these actors contributed to developing a better informed and coordinated 'landscape approach' and a landscape management plan. On this basis, the platform supported planning and implementation of research and development (R&D) activities across the Mahafaly Plateau area. It has been holding regular meetings since 2011, and has fostered more focused and coordinated interventions of the different stakeholders. For example the platform initiated the development of an early-warning system for food scarcity. To this end, several cooperating organizations active on the Mahafaly Plateau (e.g. WWF, GIZ, University of Tulear, and the BMBF funded project SuLaMa) have contributed long-term data on poor harvests, droughts and resulting food scarcity.

Agricultural Knowledge and Information Systems

In the Kulunda steppe, the 'modernization' of conventional cultivation and successful implementation of no-till and minimum tillage (cultivation innovations) closely depended on the participation of the relevant local and regional stakeholders. Initially, a screening of the Agricultural Knowledge and Innovation Systems (AKIS) for key players, who support conservational soil cultivation technologies was conducted. The main players identified were research, education and extension services linked to agricultural producers, who are active in the field of sustainable land management, ecology and environmental issues and who have decision-making power. These stakeholders – who are key players – acted as multipliers of promising innovations. After the collapse of the former Soviet Union links among the identified key players of the AKIS network in the Altai region were weak to non-existent. A

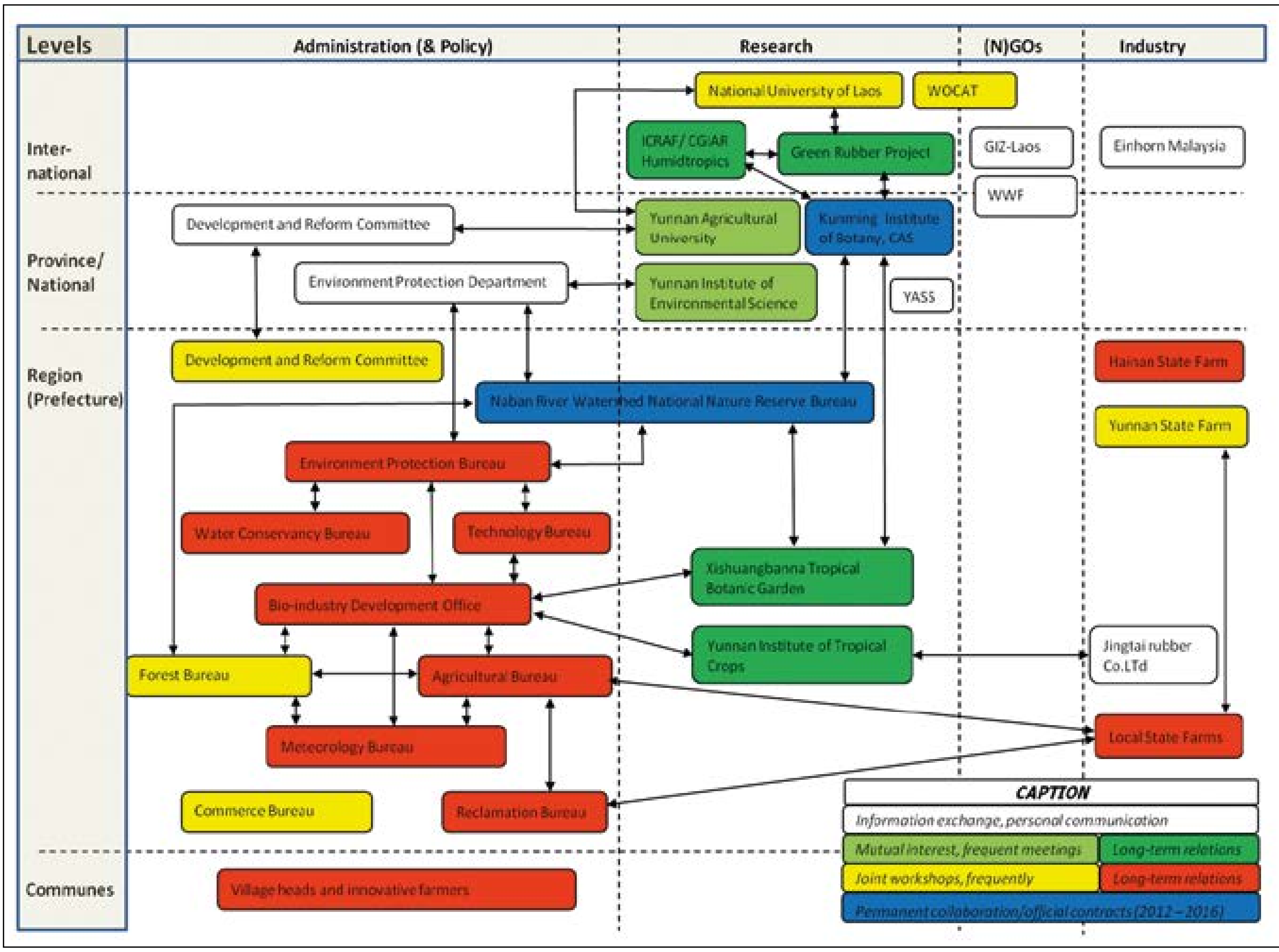


Figure 5.34: Stakeholder map - rubber network Yunnan province, China (Jue Wang and Thomas Aenis unpublished data).

more effective stakeholder network for knowledge building and transfer, therefore, was needed and has been developed with the support of the scientists working in that region (Figure 5.33).

To further improve links among key stakeholders of the platform and to enhance the extension services field days and vocational training sessions were organized (see Approach 'Field days' page 255 and Approach 'Vocational training' page 259).

Identifying key stakeholders

Stakeholder dialogues for more sustainable rubber plantation management in Yunnan province, China, helped to address key issues for the local and regional stakeholders. Stakeholders numbered, among others, innovative farmers, regional decision-makers and rubber companies. The target was, between researchers and practitioners, to jointly analyse and develop (potential) land management solutions. As a basis for the stakeholder dialogue, key actors in rubber cultivation, decision-making structures, and stakeholders interested in sustainable rubber cultivation, who were willing to participate, were identified. As a starting point a stakeholder map was developed, providing an overview of the most influential actors in land management in that region (Figure 5.34).

For stakeholder involvement a flexible and situation-specific communication approach was chosen. This approach included the facilitation of direct communication with and among stakeholders and the development of information material and newsletters. In particular, the establishment of focus groups and workshops with key stakeholders enhanced the communication amongst practitioners and researchers. Research was seen as a neutral agent that could initiate communication processes and facilitate dialogue between diverging interests of the various stakeholders (Aenis and Wang 2016; see Approach 'Scientist-practitioner communication' page 195).

As a starting point a stakeholder map was developed, providing an overview of the most influential actors in land management in that region. The map then was used to develop a strategy for dealing with those stakeholders. At the core of the rubber stakeholder network are the local partners with whom stable contacts (in dark blue) were established. The red colour indicates contacts to regional authorities, large companies and village heads with decision-making power. These were involved for problem identification, exchange of research results, and exploration for future scenarios. The contacts in yellow are similar to the red ones but with less intense communication with the scientists. The contacts in green (dark and light) are research institutes or research projects interested in rubber research. Their experts were involved in the workshops and via personal communication. The colourless contacts are those who have been involved for information exchange or based on personal networks, with irregular communication and less exchange. The arrows between these contacts show interdependencies amongst stakeholders, which are helpful for identifying the regional social network and are indicative of the communication strategy used.

Figure 5.35: Stakeholder workshop project Kulunda, November 2015, Russia. (Ladislav Jelinek)

5.5.3 Science – practice dialogue

Dialogue between science and practice is the starting point for transdisciplinary research. Continued dialogue helps to focus research on viable questions and problems. And it can open doors for mutually profitable exchange of knowledge and experience.

Examples

Broad dialogue and participative assessments

In Germany, science-practice dialogues (see Approach 'Dialogue platform' page 211) were conducted nationwide to allow researchers to gain important insights for coping with climate change on a regional and national basis and in turn to receive information on recently adapted technologies, their assessments and results from stakeholders. In return, researchers provided scientific evidence to underpin the often emotional discourse among multiple stakeholders with different claims for what land use can achieve towards better climate change mitigation and adaptation. On the German Baltic Sea Coast and North Sea Coast, stakeholders have been involved in an integrated assessment to develop action-oriented land management options addressing possible climate change adaptation measures as an alternative to traditional coastal protection strategies (see Approach 'Stakeholder participation' page 223). The 'stakeholder participation in integrative planning and assessment' allowed for knowledge transfer between science and practice and vice-versa. With a focus on possible solutions the following activities were conducted: knowledge exchange between researchers and practitioners, capacity building, and scenario planning of land management options together with local, regional and nationally active stakeholders.

Research-practice discourse to support implementation

In rubber plantations in south-west China, stakeholder discourse was tested for research-practice-integration, communication and dialogue (see Approach 'Scientist-practitioner communication' page 195). This approach also combined profound scientific analyses with a range of activities to enhance interaction and collaborative learning amongst practitioners and researchers.

Various aspects supporting or hindering implementation of promising alternative practices – such as intercropping of rubber with endangered native tree species (see Technology 'Native trees in rubber monocultures' page 191) – have been analysed at different levels:

- Conditions influencing farmers to implement or adopt new management options on their farms (studies of household economy, willingness to accept).
- Framework conditions/ enabling environments for introduction of alternatives (assessment of related value chains, analysis of communication networks).
- Factors influencing policy-making (objectives of different social groups in relation to sustainable rubber cultivation, decision and power structures).

In the long-run, science-practice dialogue might be one means to jointly develop and implement innovative solutions (in this case strategies for sustainable land use/ rubber cultivation), subject to the condition that they are properly institutionalised.

Discussing results with administrators

Result dissemination activities were organised in the Kulunda steppe in discussions that brought together members of the German/ Russian research teams with local policy makers, administrators and other academics (Figures 5.35 and 5.36).

Two central topics were chosen – *the design and implementation of agro-environmental policies and organisation of effective state land management.* In spite of the high relevance of these topics under local conditions, the willingness of relevant local administrators to come to the workshops, present and discuss their knowledge and experiences was limited. Besides, local actors did not actively discuss impacts of applied measures. The discussions sometimes had to be refocused on the ex post experiences with land polices in Germany or other Central European countries (e.g. the Czech Republic) to enable comparison of various approaches in the discussions. Such an experience illustrates an important historical factor: political reality and vested interests clearly restrict local and regional actors and prevent practitioners from benefiting from international cooperation and knowledge transfer.

5.5.4 Co-production of knowledge

Co-design and co-production of knowledge is one of the most sophisticated exercises in implementation-oriented research, and is still not very widespread. In the BMBF-SLM programme, which forms the background to this book, it has only partially been achieved. Most on-the-ground work was conducted by PhD candidates running their own research work. For real co-design and co-production – starting with developing the design of the project altogether – there was little prior experience compounded by a lack of time and funding; similar to the large majority of research programmes worldwide.

However, some remedial steps have been taken. As will become clear with the examples in this chapter, considerable effort was taken later on to involve local stakeholders, know better about their problems and challenges, and to communicate results in a way that they could be taken on board by land users, administrators, or members of local communities. For better contacts and involvement with members of local communities an approach was chosen that has been tested before in another research programme (BIOTA/ also BMBF funded, see Christiaan et al. 2009; Schmiedel et al. 2010).

Direct involvement of members of the local community

A straightforward method to involve people from local communities where the research is taking place is to employ them as part of the research teams. Members of rural land user communities are holders of local knowledge on the natural environment and local land use. To access, understand and incorporate this knowledge into research is perceived as intrinsically important, but also as very challenging by academic scientists. It requires special skills and sufficient time for interaction, exchange and mutual understanding. Para-ecologists can help to fill this gap and act as facilitators for transdisciplinary research. By being members of both land user and researcher communities, para-ecologists have insight into the perceptions and knowledge of communities, and can facilitate mutual understanding and knowledge exchange between land users and scientists. Para-ecologists assist natural and social scientists to collect and document environmental and household data, and simultaneously support implementation activities.

Figure 5.36: Stakeholder workshop project Kulunda, April 2016, Russia. (Altai State University press department)

Through close interaction and exchange with the para-ecologists from Angola, Botswana and Namibia, researchers who were active in the Okavango Basin, developed closer contacts with the land user communities and a better understanding of land user decisions and environmental processes. Communication with, and learning from, the para-ecologists avoided pitfalls and intercultural misunderstanding (Schmiedel et al. 2016). Furthermore the members of the land user communities benefited from the presence of the para-ecologists by having a local contact person or 'intermediary', who they can approach to enquire about the project objectives, activities and outcomes and with whom they can share their concerns about, and expectations from, the project.

On the Mahafaly Plateau of Madagascar, early involvement of local individuals and communities allowed – to a certain degree – the combination of scientific know-how with traditional knowledge, and helped identifying solutions that not only focused on short-term relief aid, but had good prospects for continuation in the long-term. The role of para-ecologists however, was not only the fostering of mutual trust between researchers and local communities. It also was important for the communication of results, better understanding and acceptance of possible alternative strategies by the local population. In the longer term, through monitoring of the impacts of different management practices, para-ecologists can also play a central role, for example in regular monitoring of biodiversity within a national park (see Apprpoach 'Participatory M&E' page 243).

This approach has been chosen by several of the projects involved in the BMBF-SLM programme; altogether with a good success rate. The employment of, and interaction with, para-ecologists certainly opens doors to all involved. Doors that otherwise would have stayed closed.

Conclusions

This chapter has presented, and discussed, approaches to implementation oriented research (IOR). It has shown that IOR can work – but there are a number of support measures that need to be put in place to make it truly effective. In summary, the main conclusions are:

Implementation-oriented research (IOR) is possible – and can be rewarding

Implementation-oriented and transdisciplinary research is certainly possible. It can be used to produce results that other kinds of research cannot achieve. Implementation-oriented research is being carried out in many locations, supported by many research funding programmes worldwide.

IOR requires support from all involved

Implementation-oriented work needs the support of research institutions from the partner countries where the research takes place. It is a great help if funding is available to cover this cooperation, and funds that supports both young and experienced scientists from the countries of the studies. The success of IOR also depends on the support and ingenuity of members of local communities, of advisory capacities available for the topics, the implementation challenges at stake, and on successful involvements of regional and national decision-makers. For cooperation on all these levels, adequate timeframes, working in good partnerships, as well as diplomatic support (with recommendation letters from the funding organisation, GIZ, the Federal Foreign Office or others) can be very useful; indeed often essential.

Involve people from practice from day one

Local people from the practical, on-the-ground, element have to be involved from day one of the overall project work. They are needed because of their contributions to understanding of local conditions, observational skills, knowledge creation, and practical experience. If concrete results and recommendations emanating from the implementation-orientation of a project are to be relevant, then the researchers need to sit together with 'people from practice' as early as possible. The challenge here is to not only define the research objectives and research questions but also the implementation-oriented objectives of the project. This can only be done together with those who know what is being talked about and who in the end can act on decision-making tools, SLM planning, and the design of potential new land management technologies.

Needed: highly experienced coordinators and knowledge managers

IOR also needs strong competences from experienced coordinators of the individual research projects: they face challenges of science management and science communication, that go far beyond the normal; 'normal' being the coordination of a disciplinary project with exclusive participation of researchers. Coordination in IOR does not concern only, or even foremost, management tasks. The most precious coordination covers knowledge management and the facilitation of joint learning. For projects with many heterogeneous partners from science and practice, at least one coordinating post dealing with project management (managing meetings, conferences, joint reporting) and another post of scientific coordination for bringing together and synthesizing the different kinds of knowledge (practice-oriented, target and/or profit oriented, academic/ scientific, strategic, indigenous/local knowledge) are required. Universities should be given strong financial incentives to systematically build-up competences for knowledge management and facilitation of inter- and transdisciplinary learning, as people able to meet such requirements are few and far between: but more and more urgently needed.

Enable and empower intermediaries

People in the participating study regions can be enabled and empowered. Sharing knowledge and understanding, and communicating it in a way that it supplies clear choices for decision-making is meaningful for all involved. Successful cooperation and communication methods such as farmer field visits, education days for school children, awareness videos and TV series best succeed in close cooperation between research and intermediaries such as river basin committees or inter-ministerial units. The work to be attempted with these partners can be challenging but achievements can also be surprisingly successful when bringing about unexpected new experience and knowledge. And it can be satisfying for all involved.

Involve professional communicators/ change managers

The involvement of professionals for tasks such as communication, project management, coordination and facilitation of meetings, reporting for internal and external evaluations, or stakeholder analysis and stakeholder involvement needs to be carefully considered. There are two options for coordinating research partners: either to build up these competences with a long-term commitment inhouse, or to outsource (at least some of) the required management and communication skills. With either option, universities and other research partners would be able to better focus on their key competence of conducting the required research.

Methodology mix and the value of experience

Tools and methods for communication in IOR contexts have been available now for some 25 years from experience with inter- and transdisciplinary research as well as from other areas such as development cooperation, media sciences, or journalism. Here an open and flexible approach is important: analysing what is particularly needed for the individual project and to utilise what analysis and communication tools fit best. Furthermore, it can be of great help if prior experience such as 'awareness filming' with the help of para-ecologists (members of local communities working as research assistants) can be integrated. Not all approaches for fruitful cooperation need to be designed from scratch.

Openness to listen and learn

Irrespective of what 'approaches' are taken, openness to listen and learn about formerly undiscovered areas is fundamentally important:

- openness to other cultures and other walks of life, 'their' and 'our' often very different ways of dealing with problems and challenges, and the different possible solutions;
- preparedness to carefully listen, and try to understand other experiences and interests;
- development of mutual understanding and acceptance of different kinds of knowledge;
- flexibility with planning of meetings, visits or workshops, concerning the participation of key partners, patience with very different time horizons and approaches to work; and last but not least;
- flexible expectations of results, and preparedness to be surprised also in this respect.

Co-design, co-production, co-delivery: new career paths for scientists required

At present there remain conflicts of interest between what is required from the perspective of the funders and the interests of scientists themselves when working in IOR programmes. The funders require stakeholder involvement and work towards practical implementation. The scientists involved need to finish their PhDs or want to publish in – predominantly disciplinary – academic journals. This conflict of interests becomes obvious when it comes to tangible stakeholder integration. With local stakeholders, there are multiple other elements of importance: their own specific interests, commitments, expectations, and time horizons.

But co-designing research work and co-defining implementation-oriented objectives is a key pre-requisite for successful joint work when practice-oriented results are aimed at. For such co-design of IOR it is necessary to give up the hierarchy of interpretation and established traditions of designing topics from scientific perspectives alone. If PhD candidates have to write disciplinary doctorates, then IOR, basically speaking, is not really attractive for universities and many other academic partners. Here it is only new career paths for IOR in which young scientists can safely make a long-term scientific career that could help to change the name of the game. With all these challenges, supported by experience, it is time to think again – and more thoroughly – about what is needed for truly effective IOR.

CHAPTER 6

The contribution of research

Southern China, Gerhard Langenberger

Introduction

One of the central challenges of sustainable land management (SLM) is its complexity. Land is 'multi-dimensional' in its various connections, functions and relevance.

It is:

- **multi-scale:** connected to local, regional, national, and international levels;
- **multi-functional:** relevant to productivity, ecosystem function, biodiversity, water, climate issues, disaster-risk reduction, and livelihoods;
- **multi-sectorial and multi-stakeholder oriented:** connected to individual land users, development agencies, the private sector, government and non-governmental organizations, planners and decision-makers;
- **multi-tenurial:** connected and related to ownership and resource use rights; and
- **multi-disciplinary:** related to natural sciences (e.g. soil, water, plants, animals) and social sciences and humanities (e.g. economics, governance, values).

When developing strategies and solutions for sustainable land management these multiple perspectives and interrelations have to be taken into account. The implementation-oriented research on which this book is based integrates three main topics: land management, ecosystems, and climate change. Although they are closely interrelated and intertwined, they are often treated separately – in science as well as in practice. Facing this multi-dimensional complexity of land leads to challenges for everybody involved: scientists, land use planners, administrators, politicians – and, of course, farmers and other land users. Thus a relevant scientific approach must include interdisciplinary integration and stakeholder involvement to make a relevant contribution to SLM practice and to support evidence-based decision-making. Research can make a unique contribution, through analysing possible synergies and identifying trade-offs that come into play *if* the 'multi' character of land is taken into account.

6.1 Tools and methods: the ways and means of conducting research

Science that is intended to solve practical problems needs to be underpinned by reliable data: but that takes considerable time and effort, and often this is not appreciated. Compiling and analysing datasets is the first step in research and development. It is the basis for scientific key methods and tools, including models and scenarios. Models and scenarios may be used for designing and testing the impact of different land managements and innovations under different conditions (e.g. climate change) and thus identify promising options and solutions. This can be an important support for decision-makers at various levels: for local land planners, regional water authorities and national policy makers, to name a few. So what are the methods and tools that science has at its disposal to help with sustainable land management research?

6.1.1 Data collection, analysis and monitoring

At the core of any research activity is data. Collecting, organizing, analysing and interpreting data in a systematic, verifiable, and objective way is science's key competence. In the case of land management research, teams of scientists from different disciplines have to work together – because of the multiple facets of land that we have already set out. Thus scientists need to take scope and complexity into account by collecting and combining data from various aspects of land management.

Existing datasets have to be located and requested. Especially important are long-term datasets. These are key to shed light on the current state and trends. They are also needed for the verification and calibration of computer-based models that describe the interactions within land management related systems. For assessments of interactions between land management at different levels of scale, researchers need data from the field or plot, the village, the municipality, the watershed, the region, the country, and sometimes beyond national boundaries. Long-term monitoring provides these datasets. But these are rare: such data collection is often not carried out, and seldom on every relevant aspect of land management. Sometimes datasets are lost. So, although this long-term data is key for informed planning and decision-making, it is rarely available. Filling data gaps and building up monitoring capacity, therefore, is a crucial task for current – and future - research activities (see Approach 'Participatory M&E' page 243).

Sometimes researchers can build on existing monitoring programmes. In these cases collaboration on the basis of mutual interest is the key to data access: building trust and 'giving back' in return. This has not only to do with scientific data. When people or institutions provide information it is critical that they can also profit from the research. Instead of a one-way flow there should be a continuous feedback cycle between researchers and providers of data. Too often data collection is simply extractive.

Researchers can identify gaps in existing datasets, identify knowledge gaps, and build on these. Then they carry out their own measurements, field experiments and surveys. Key persons are identified and interviewed and essential biophysical aspects are measured. Ideally, natural and social scientists work together: however this requires careful coordination and commitment. But the integration of research results from all involved disciplines produces more consistent and relevant outcomes for planning towards improved SLM.

Integrated report and meta-database on the state of the River Basin

The systematic collection, organisation and professional communication of data across different land related aspects and sectors provides support for making adequate and efficient land and water management decisions. Strategies and action plans can then be developed on the basis of robust and reliable data. Actors involved in decision-making and planning can theoretically access well-processed and structured information, integrated across all relevant sectors and scales. However, in practice this rarely happens. Information is usually scattered in many sectors and is hard to come by. Baseline data and reports providing an overview of the bio-physical, current socio-economic and institutional environment of a region or watershed are much appreciated by various stakeholders and users. The 'State of the Basin Report' of the Vu Gia Thu Bon (VGTB) Basin in Central-Vietnam, for example, supports better understanding of the current condition of land and water resources in the river basin. It integrates a wide spectrum of information relevant for decision-makers, land management specialists, researchers as well as land and water users in the region. Another way of providing access to structured information is a meta-database (a database of databases) – as was realized for implementation-oriented research on the Brazilian São Francisco River Basin. This research started as an organized way of storing information derived from primary research and secondary data, made available online via a joint geoportal interface. Such a portal can be a nucleus for a larger database, organizing all studies and materials relevant to a given watershed (link: https://catalog-glues.ufz.de/terraCatalog/Start.do;jsessionid=80F6A3D2C446674B898881D0589887E4).

6.1.2 Developing and using models

Computer-based models are a well-established scientific approach to describe and understand a complex system. In understanding what models can do and what their limitations are, it is necessary to differentiate between:

1. Models which provide a simplified representation of a selected part of reality. The selection can be spatial, describing a specific region, and/or topical, describing a specific issue like climate. A choice is made on the level of detail, often depending on data availability.
2. Scenarios which use models to help assess ('project') future developments and their likelihoods or test management options and assess their effects (e.g. impacts of land use change on the climate).

Basically modelling can provide an insight into the interactions of socio-economic and natural systems related to land management. Because of the complexity, separate models describing various aspects of the system (e.g. carbon cycle, carbon sequestration, erosion, ecosystem services, water cycle, socio-economics and labour) are combined. This integrated 'model architecture' can be applied either at the local level, investigating different land management practices and climate change scenarios, and/or at the landscape level, where models have the potential to integrate local land management practices and show the impacts of their combinations within the larger landscape.

A typical challenge for research and the use of models is to address complex interactions and dependencies within a watershed; for example of reservoirs built and the water storage and release regulated for downstream users. There will be questions such as: What is the amount of sediment inflow into the reservoir? What are the consequences on the storage and the downstream sediment load? What is the minimum water flow for downstream users? What is the optimal balance between hydropower generation and water availability for irrigation during dry seasons? And: How is it possible to regulate and minimize the damaging impacts of floods and droughts? Each of these can be addressed with appropriate models.

Models based on *quantitative* data can be used, for example, for the description of the effects of different land management practices on productivity, soil biodiversity, and water demands.

Models based on qualitative data are used to visualize complex interrelationships amongst users, decision-makers, resources, and regulations (e.g. 'constellation analysis', see Approach page 175 and Video) in order to detect driving forces and barriers. When new models are developed, or existing ones are combined, the time needed for model testing and calibration/ validation, and actually running scenarios is often underestimated. It can take years and considerable effort to develop and adapt models – and get reliable results.

For the incorporation of knowledge from local or regional stakeholders in model development repeated rounds of workshops are necessary. These workshops should also support trust building in the modelling exercise and its results.

Models are used for specific purposes and thus have to be robust enough to produce reliable results but also reflect the complexity needed. Therefore, prioritization is important. New and better structured models can improve our understanding of complexity (with suitable model architecture). Alternatively, existing models with newly developed user-friendly applications can fit the purpose. In implementation-oriented research (IOR), modelling can be used as a tool to facilitate collective decision-making processes and to foster knowledge exchange between different stakeholder groups. When discussing a model during workshops, stakeholders from various backgrounds tend to develop a deeper, joint, understanding of the cross-cutting nature of land management. As a longer-term planning tool scientific models are often used as a basis for Decision Support Systems (DSS) (see Chapter 6 page 137). The following gives an overview of the range of possibilities of modelling by describing examples used in very different contexts.

Combining existing models to assess land management options in a river basin

This example demonstrates the variety of already existing models capturing different aspects of the overall land management system of the São Francisco River Basin, Brazil. The models were combined to better understand water, land use, climate interactions in the region, and to make facts and their interrelationships more transparent as a basis for decisions-making (Table 6.1).

Some of these models are aimed at decision-making based on existing simulations. This category of models concerns topics and challenges such as water quantity (SWIM), hydro-economic conditions, hydrodynamic calculations, water quality (Moneris), global land use (MAgPIE), and biodiversity modelling with MaxEnt.

SWIM simulates future water quantities and river flow under different land use patterns (MAgPIE results) and includes different climate change scenarios (Figure 6.1). The aim of these modelling efforts is to better estimate how much water will be available for agricultural irrigation, hydropower generation and other uses in the future. A model-based upstream/ downstream water management system has been proposed for improved allocation of water, including different options for integrating the ecosystem of the region into the model as a 'water user without a voice'. All simulations are exemplary calculations, meant to feed into the prioritization for water allocation and resultant decision-making.

How models are combined depends on the questions that they need to answer. For example, a specific model architecture was built to assess impacts of land use change on soil productivity and fertility, biomass production, watershed functions and environmental services in small mountainous catchments in southern China. LUCIA (Land Use Change Impact Assessment) is a dynamic and spatially explicit landscape-scale model (http://lucia.uni-hohenheim.de). Emphasis was on material flows in the landscape that connect upland/ upstream and lowland/ downstream areas.

Model name	What it describes	What it can be used for
'MAgPIE'	Global land use allocation influenced by population growth, climate change, trade (São Francisco River Basin in high resolution)	Designing plausible scenarios for future land use pattern (e.g. input into SWIM, hydro-economic model, Moneris)
'SWIM'	Climate and land use change impacting water availability in the São Francisco River Basin	Testing management scenarios: how much water is available if managing reservoirs in a specific way, or, what management is required to reach a target (and discharges as input into hydro-economic, hydrodynamic and Moneris models)
'Moneris'	Nitrogen and Phosphorus emissions into the São Francisco River Basin	Detecting dominant sources of emissions in order to direct action at the major polluters
Hydrodynamic models	2D or 3D representation of water dynamics at different scales	Estimating the retention time of pollution and direction of dilution movement in a given stretch of the water body (e.g. how will pollution spread when starting new net-cage aquaculture?)
Hydro-economic models	Water demand under current/ future land use patterns, water infrastructure and technical, environmental, and institutional constraints (semi-arid region of the São Francisco River Basin)	Suggesting an economically efficient water allocation based on the economic value of water and evaluating economic effects of operational reservoir rules, environmental flows and institutional constraints
'MaxEnt' biodiversity model	Species habitat and species distribution for the area of one specific natural biome (*Caatinga*)	Identifying patches for prioritization of conservation (hotspots or coldspots)

Table 6.1: Different models applied in the São Francisco River Basin, Brazil

The model architecture consists of five main modules:
- Hydrology/ soil water
- Soil nutrients
- Organic matter decomposition
- Plant growth
- Land use and management options.

Assessing impacts of climate change on biodiversity and ecosystem services

Models can also be used to assess future environmental conditions and their impact on species distribution and ecosystem service provision; for example in relation to climate change and sea level rise. Here modelling can be an important tool to better understand the challenges that may arise in the future, and to evaluate possible solutions.

In a collaborative German modelling project the following mechanism has been established: as a first step, climate simulations based on different emission scenarios, as well as assumed sea level rises, are used to determine the hydrological conditions in the region simulated for the period from 2010-2100. In a second step, species distribution models project the occurrence of plant species in the landscape, based on the modelled hydrological conditions, the known (and assumed constant) soil characteristics and probable land uses. The models thus integrate data from different sources of the inter- and transdisciplinary work, and quantify the spatial and time-bound conditions. In a final step, the future hydrological conditions, land use and plant species distributions are used to calculate the ecosystem services (Figure 6.2). Thus, changes over time as well as trade-offs and synergies of ecosystem services can be analysed for the whole scenario period of 90 years.

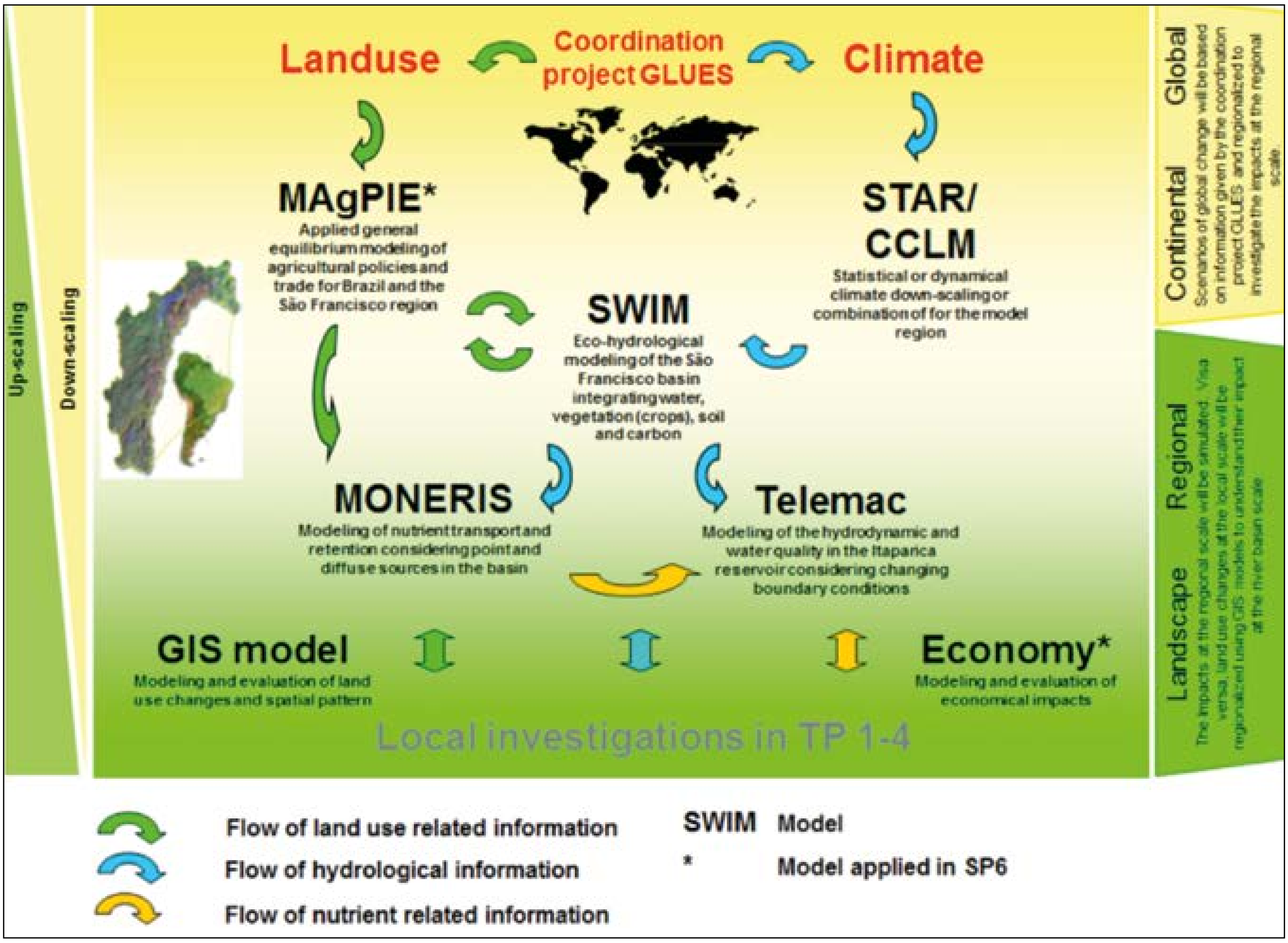


Figure 6.1: Overview of the model architecture for the São Francisco River Basin, showing the combination and interaction of the models described in Table 6.1, covering land management and water aspects across different scales, and information flow between the models. Local investigations are carried out by subprojects (TP/SP) (Hattermann et al. in preparation).

Based on this chain of models it is possible to analyse the effects of a changing climate, sea level rise and changing land use on ecosystem services. This helps us to understand how sensitive a landscape is to environmental and land use changes, and enables an analysis of possible solutions to address changing climatic conditions over a long period of time time (http://geoportal-glues.ufz.de/comtess_app.html).

Combining models at different scales

To study the hydrogeology in south-west Madagascar, where water scarcity is one of the key challenges, it was essential to distinguish between large-scale hydrogeology in an area of about 40,000 km^2 and small-scale hydrogeology in selected villages and their surrounding area (100 km^2). At the larger scale, rough estimates and information from literature were used to develop a general understanding of the hydrogeology of the area (Figure 6.3). In the target villages of the project, detailed investigations combined with framework conditions calculated by the large-scale model permitted estimates of the local hydrogeology. General hydrogeological methods and assumptions were combined with the results of specific field studies, especially focussing on wells and groundwater.

Groundwater levels vary considerably with the geological conditions providing varying accessibility to water for the people living in the area. Three target villages in different geological areas were studied in more detail to assess groundwater levels and recharge as well as rainwater availability during the rainy and dry season (Figure 6.4). On the plateau, the major aquifer is only accessible through deep drilling and pumping stations. Alternative water sources are small, very localized, 'perched aquifers' (Figure 6.4 and 6.5). In areas where aquifers are too deep for wells, rainwater is collected during the rainy season in local catchments (*sihanaka*) which provide water for about two months for daily drinking, cooking and washing – as well as for watering livestock. In the coastal areas, groundwater is easily accessible but if it is overused the region is prone to salt water intrusion which makes water unsuitable for human or agricultural use. The small-scale models help in understanding the specific situation, and indicate under which conditions water availability can be improved by appropriate methods.

Empirical Agent-based Land-use Modelling

It is not only natural conditions that can be modelled, but human behaviour too. This method is based on 'agents' (people in specific roles, e.g. farmers) whose decisions in reaction to changing environments determine the development of the land use. The agent-based model SEALM (SuLaMa Empirical Agent-based Land-use Model) was used in Madagascar to understand the complex interactions and feedback loops between land use and land cover changes (LULCC), deforestation processes and ecosystem services. It allows the simulation of possible future trends in land use and explores smallholder farmers' coping strategies with respect to food insecurity. The modelling results are helpful to identify hotspot areas of LULCC and forest fragmentation in time and space. The model consists of different types of 'entities', which include the landscape, households, livestock and climate (Figure 6.6). For the design of those entities, a wide range of data was used, incorporating social surveys, high-resolution remote sensing and field-based validation data.

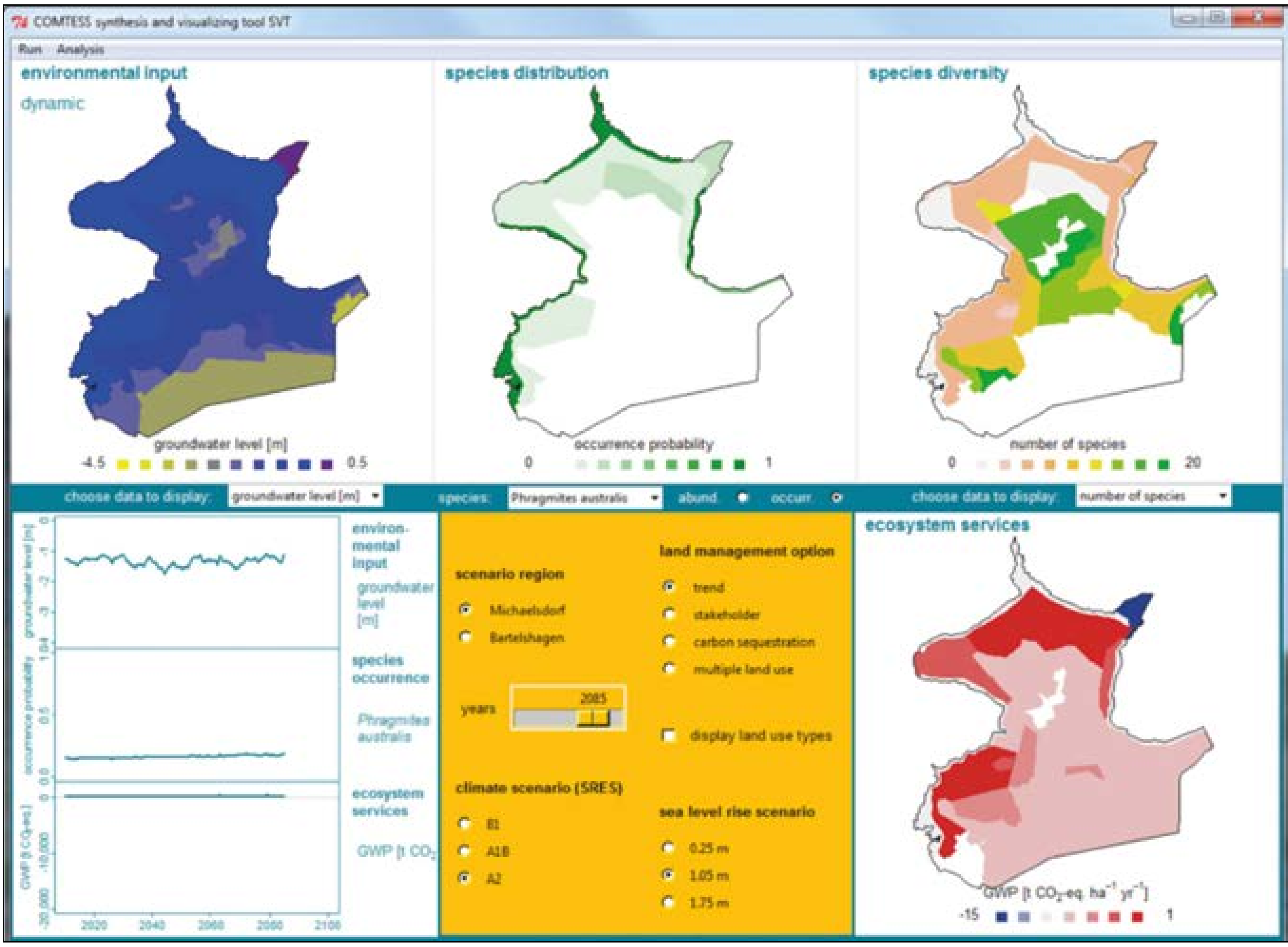


Figure 6.2: The COMTESS SVT (synthesis and visualizing tool) to present spatial and temporal explicit data. The tool can show distribution for selected species under different climate scenarios and sea level rise scenarios for different land management options. Here: Peninsula Michaelsdorf (German Baltic coast) in the year 2085 under climate scenario SRES A2 for a land use 'trend/ business-as-usual' scenario and a sea level rise of 1.05 m (GWP = global warming potential). (COMTESS)

The model represents six important steps carried out by 'household agents' – the farmers – related to land use: (i) ex-ante planning and labour allocation (before action is taken); (ii) field extension; (iii) field preparation; (iv) crop cultivation; (v) harvest; and (vi) ex-post-planning (reflecting the land use decisions after harvest) and selection of coping strategies for the next cycle. For each step, households may use different adaptation mechanisms to avoid food insecurity and increase household income: increasing or reducing the area of cultivated land depending on available capital and energy requirements, changing the allocation of their agricultural fields or altering their coping strategy dependent on available livestock, farm-income and capital.

Within a geographical information system (GIS), maps related to bio-physical and socio-economic data were compiled from existing information and field surveys (e.g. land use, land cover, soil quality, biomass, crop yield and land ownership). Forests were additionally characterized by information relating to the forest use potential (e.g. biomass stock and growth rate), which can be determined through remote sensing and forest inventory data. The livestock module simulates different grazing and herd management strategies and the resulting effects on vegetation and land cover changes.

Global driving forces are selected that directly affect the state of the model variables and household activities such as population dynamics, climate conditions, protection of forest resources and fallow periods. During model set-up, the global variables can be changed in the user interface to simulate multiple scenarios (e.g. different climate scenarios, population increase or different crop management strategies). Simulation outputs are explicit concerning space and time, and include maps of the landscape enabling the analysis of habitat fragmentation, changes in forest area and biomass stocks. Socio-economic outputs include food security (food self-sufficiency), crop yields, household income, availability of fuel and construction wood, and related coping strategies. The simulated scenarios and the underlying data of all maps and graphs can be exported to electronic files for further analyses and interpretation.

6.1.3 Developing scenarios

Scenarios are descriptions of possible future developments under various assumptions termed 'projections'. They can be of predictive nature describing a specific development with regard to its probability. Or they can describe the future consequences of specific management decisions. Thus: *'If we implement this regulation or technology then it will have this effect on land productivity, ecosystems and climate'*. 'What-if' scenarios enable researchers to assess the possible impacts of different land management choices, help decision-makers to think about different options and explore possible or likely results.

Because of the 'multi-dimensional' nature of land management, several scenarios are run on the computer models so that results can be compared. They can be based on a set of concrete management choices (e.g. technologies or action plans) or on the optimisation of different goals (e.g. mitigating climate change, conserving

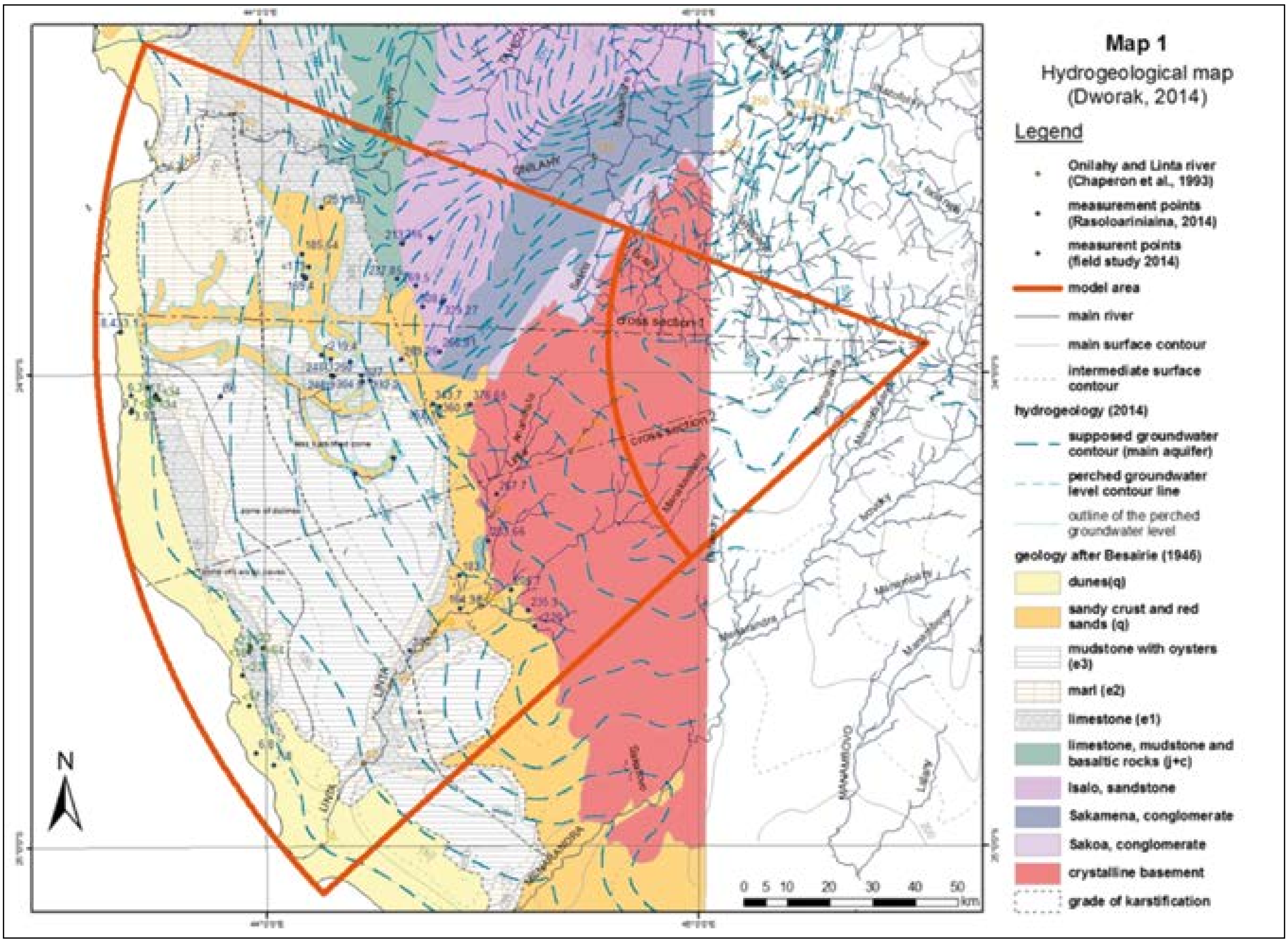


Figure 6.3: Hydrological map of the large-scale model giving an overview over the region (about 40,000 km^2 in total) from the Mahafaly plateau to the coast showing the distribution of the different geological conditions, Madagascar (Dworak 2014).

biodiversity, improving resilience or increasing productivity). These 'choice' scenarios' are compared with a baseline scenario, called 'business-as-usual' or 'current trend' in which the conditions in the model are based on the present situation without policy or management changes.

Comparing the impacts of different scenarios reveals trade-offs and synergies between the selected management options - for example, between the goals of optimizing food production and conserving biodiversity by applying different measures at local and landscape levels. Complex model architectures allow the assessment of complex systemic interactions – for example, assessing the impacts of land management decisions on natural ecosystems and socio-economic systems under different climate change scenarios, and vice-versa, impacts of natural ecosystems and socio-economic systems on land management and its effects on the climate. This allows us to take climate mitigation and adaptation aspects into account in a single assessment. And this could help decision-makers to develop land management strategies that combine different goals and needs.

Scenarios can support different levels of decision-making. Detailed models at the local level describing the interactions of soil, plants, and water with possible climate developments can help to optimize a farmer's decisions on timing of sowing, harvesting, irrigating or the choice of crop. Through scenarios, planners can test how the spatial arrangement of settlements, green and blue spaces and fresh air corridors can reduce overheating of cities. At landscape level, a typical example of the use of scenarios as a basis for decision-making is integrated river basin management. 'What if' scenarios are developed to explore the likely impacts of different land and water management options, for example: *what are the implications and economic effects on hydropower generation and other water uses if a minimum flow during the dry season has to be guaranteed, or if the fluctuations within the reservoir should be less than 0.5 m per year and less than 5 cm per day, and if irrigation during the dry season needs to be doubled?* On top of all these management questions and their downstream implications, climate change scenarios can be introduced to visualise the impact if, say in 20 years from now, the amount and distribution of rainfall is different (see Chapter 2).

At the local and landscape/ regional level, scenarios have been used as a basis to develop action plans for sustainable land management by addressing problems and suggesting possible future changes. An important aspect of those scenario development exercises is raising awareness of future problems and adapting land management strategies well before the impact becomes visible. This concerns climate change, as well as impacts of continuous intensification of land use and expansion of agriculture, settlements and infrastructure (see also Chapter 5). Beyond improving the scientific understanding of the human-nature interaction and its use for knowledge-based decision-lanmaking, scenario development is also used as a tool to integrate different actors into participatory scenario development. In an iterative planning process the participants develop a mix of measures and can arrive at a compromise based on their different, and sometimes conflicting, interests. Such a process can enhance joint understanding of complex systems, and can foster knowledge exchange and discussion between stakeholder groups with vested interests (see Approach

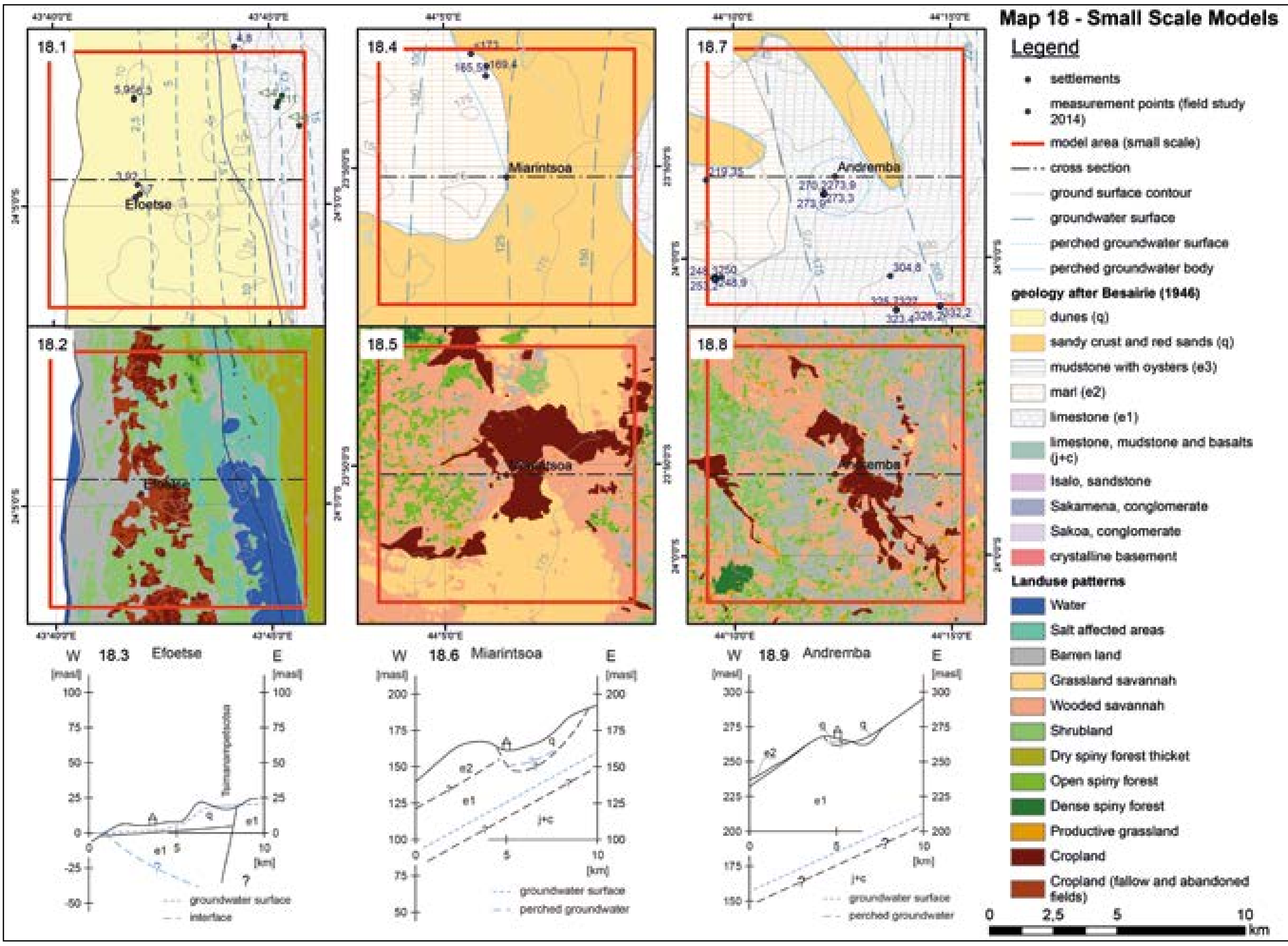


Figure 6.4: How modelling can zoom-in from the large-scale to the three selected villages in Madagascar where detailed measurements were carried out. To investigate the variety of water conditions, the villages were chosen on the basis of their different geological and hydrological conditions (Dworak 2014).

'From storylines to scenarios' page 163, Approach 'Stakeholder participation' page 223 and Technology 'Polders to improve water management' page 215).

Scenarios for evidence-based decision support

For a nation-wide process and for different regions in Germany, scenarios were developed jointly between all stakeholders through a series of workshops and interviews, in order to provide information for evidence-based decision support for policy making (Figure 6.7; see Approach 'Dialogue platform' page 211).

At national level, four scenarios were designed, each focussing on one of a series of societal goals: climate mitigation; production of biomass for bioenergy; nature/ environmental protection; and climate adaptation for a time period of 2010 to 2030. These were compared to a business-as-usual scenario. The scenarios were built on recommendations and feedback by stakeholders from the main sectors: agriculture, forestry, nature conservation, settlement and transportation.

The outcomes from running those scenarios on the model architecture depicted the distribution of land use (farmland, forests and settlement and transportation, recreational areas, and newly built-up areas) spatially explicit on a 1 km raster. For each land use scenario, economic figures covered production, yields, operating costs, effects of fertilizer/ manure, environmental impacts, and the reduction potential of greenhouse gas emissions. Spatial development in one of the focus regions was of particular interest to the regional planning administration. At the national level, regional impacts of re-wetting organic soils was an important focus. Here it is of special interest where counties have particularly appropriate natural conditions for re-wetting and what consequences re-wetting of organic soils would have on food and fodder production, agricultural income, and reduction of GHG emissions (see Chapter 3).

In the coastal areas of Germany, another scenario development exercise tested land management options and raised awareness about upcoming challenges – which are not currently urgent but

Figure 6.5: Groundwater-fed pond in the village of Efoetse on the coastal plain of Madagascar. Groundwater levels are influenced by sea tides, and over-exploitation leads to increasing salinity of water – while water quantity remains constant. (Andreas Englert)

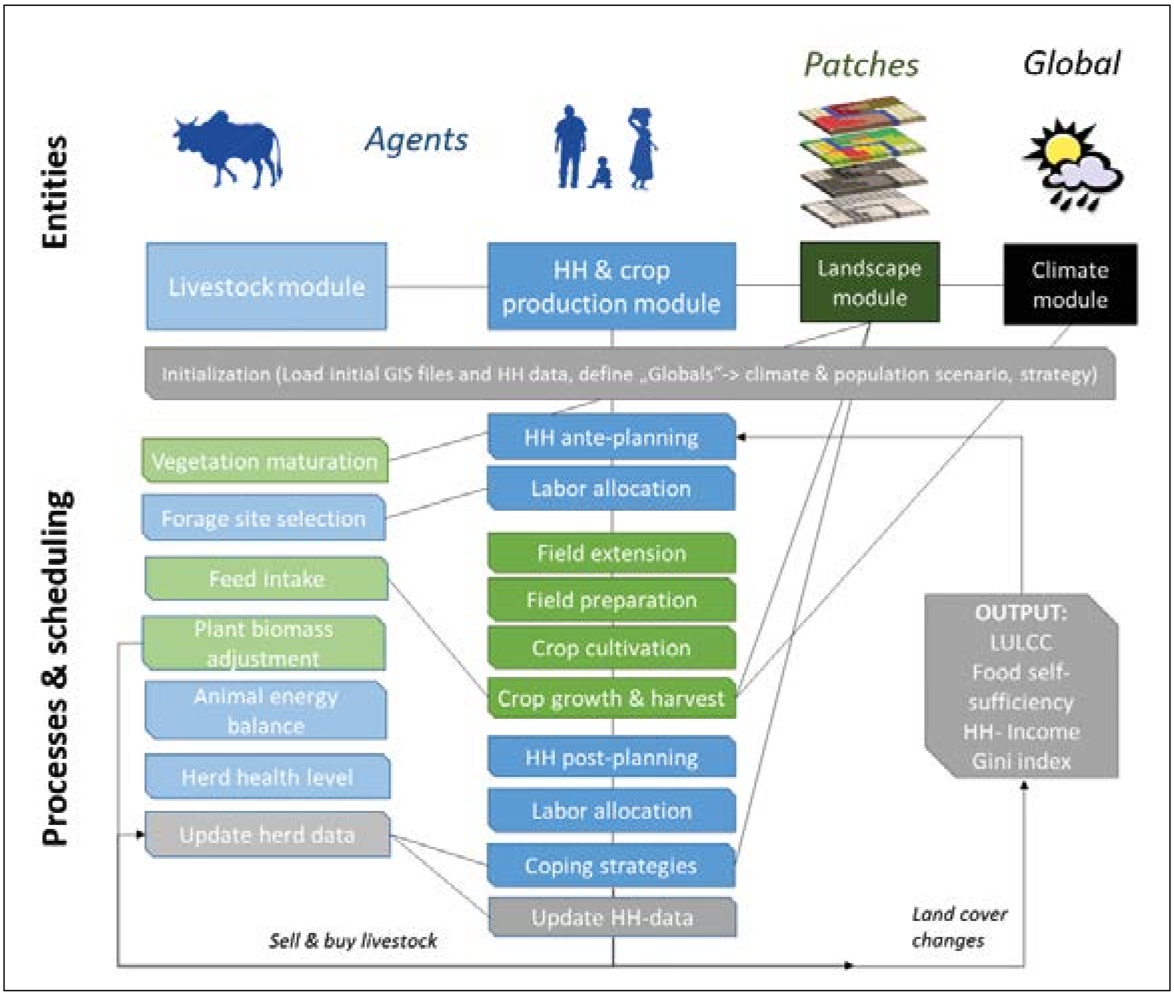


Figure 6.6: Entities, processes and scheduling of the SEALM modelling approach in Madagascar: SEALM allows the simulation of potential future trends in land use and explores resultant smallholder coping strategies. SEALM: SuLaMa Empirical Agent-based Land-use Model, HH: households, LULCC: land use land cover change. (Katja Brinkmann)

will have significant impacts in the future. The focus of these scenarios were strategies to adapt to a changing climate and consequent sea level rise (see Chapter 2 page 70). Options of optimizing water management and optimizing climate change mitigation were explored. Based on these options one integrated scenario was developed together with stakeholders from the region. They used these scenarios as a basis, and pooled them with their own ideas to develop a vision for the future (see Approach 'Stakeholder participation' page 223 and Chapter 5 page 121). Comparison of the pre-defined strategic scenarios (trend, water management and climate change mitigation) with the stakeholder scenario indicates and illustrates consequences of future alternatives. The overall exercise supports the value of development of strategies and adaptive solutions, co-designed with all stakeholders. Thus, scenarios were used as a basis for framework development for sustainable land use management within the region, addressing actual or expected future problems (see 6.2.3 page 140).

6.1.4 Developing and testing innovations

At a very practical level, innovations for improved land management were developed and tested either in field experiments jointly between researchers and local land users, or by the scientists alone within experimental stations or on rented plots. On a larger scale, innovations in landscape management were tested in model-based scenarios. For the concrete development of innovations, a combination of outsider and insider perspectives proved to be fruitful. When local scientists work together with scientists from other countries they contribute different contextual perspectives.

Both researcher groups, however, often have a very different view of the problems at hand than practitioners. Only a constructive combination of all these viewpoints can lead to ideas and possible solutions that are evidence-based, robust, and applicable under the given local and regional contextual and framework conditions. It is important to appreciate that a 5-year timeframe, at least, is needed to observe longer-term effects – for example impacts of land management practices on the increase of soil organic matter, or on the recovery of ecosystems. To produce more reliable results longer timeframes of research projects are essential to support the development and adoption of innovations (see 6.2.3 page 140).

Examples from different regions

Within different contexts and regions a set of concrete technologies have been developed. These are described in more detail in Part 2 of this book.

- In the **rubber plantations of southern China**, intercropping with native tree species was tested and introduced by the researchers (see Technology 'Native trees in rubber monocultures' page 191). Based on the analysis of the negative impacts of the monocultures, this solution was developed on a test site, which also served as a demonstration plot for the rubber farmers in the region.

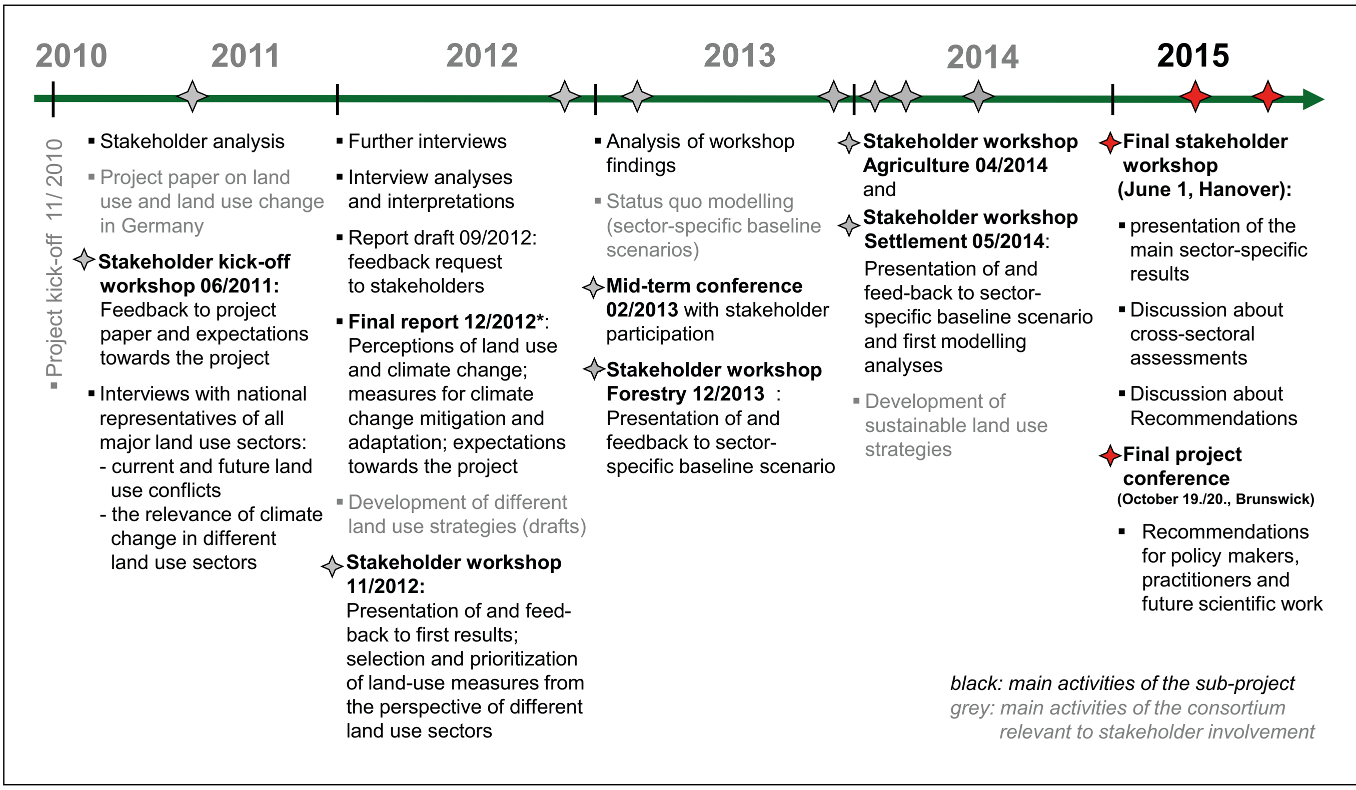


Figure 6.7: Timeline of a model-based scenario development with feedback loops with stakeholders from different land use sectors, Germany (Hellmich et al. 2015).

- In **southern Siberia**, scientists cooperated with a local farmer and a company for agricultural technology to improve machines for large-scale no-till farming in the specific conditions of the Kulunda steppe (see Technology 'Minimum tillage' page 251 and Video). The test farm was used jointly by the three parties to develop the innovation. It also served as a demonstration site for the field days to inform other farmers.

- On the **Mahafaly plateau of Madagascar** scientists identified the over-harvesting of the fodder tree *samata* (*Euphorbia stenoclada*) as one of the drivers of land degradation and depletion of the wild *samata* population. Together with the local people they developed a method of artificial *samata* propagation that should reduce pressure on the wild population, while improving fodder quantity and quality and thus animal health, which in the long term increases income from animal husbandry (see Technology '*Samata* propagation' page 227, and Video). Furthermore, a comic-illustration targeting local people – many of whom are illiterate – contrasts the advantages of more careful *samata* harvesting practices with the impacts of the common practice which increases overexploitation.

- At the **Itaparica reservoir in north-east Brazil** a test site was installed on a rented plot in the middle of a village. Here *umbuzeiro* (*Spondias tuberosa*) tree planting was demonstrated in order to restore this indigenous, multi-purpose species (see Chapter 1 page 42). This would help sustain rural livelihoods and at the same time preserve natural biodiversity. On this same plot soil amendments were also tested, comparing the effects of clay sediments from the nearby water hole, biochar and goat manure. This same soil amendment experiment was also carried out in the experimental station of a state agency for research and extension to compare results in a controlled environment.

- A so-called 'green liver system' – a natural water purification measure – was installed as a prototype in the area of a large **Brazilian aquaculture farm** to purify the effluent of fish ponds before their release into the reservoir: apart from the obvious environmental benefits this meant compliance could be achieved with environmental norms of water quality (see Technology 'Green Liver' page 167).

6.1.5 Supporting decisions

Making informed decisions in a complex context like land management is difficult when knowledge is dispersed and disconnected. Inter- and transdisciplinary research produces and integrates knowledge and different perspectives on the same problem topic. When well-communicated, in a form and timing appropriate to the target groups, those research results lead to more integrated and systemic solutions for sustainable land management. They can be participatory and democratic also if they answer land users problems – and solutions are presented in a way that allows adaptation by the end-users.

Several of the above mentioned methods and tools form the basis for decision support at different levels of scale: from farm level to international cooperation within a river basin. They also address different levels of complexity related to, for example, choice of crops, methods of agricultural production, water management along a river, landscape management in a whole catchment, regional spatial planning, and national climate adaptation strategies.

Decision support, for such challenges, is intended to:

- **Provide information on the current status:**
  Organize data in databases, publish the results of surveys, assess and analyse the current state of a land management system, and identify the drivers of change and inform about causes of problems. For example, rubber farmers usually do have a clear idea about problems of water quantity and erosion, but they often don't connect those problems with their rubber cultivation practices.

- **Present research results on management options and their impacts:**
  Identify and describe land management options. Develop scenarios with decision-makers and assess their impacts. Facilitate 'back-casting' exercises to support planning within existing planning bodies and commissions: in 'back-casting' different land management options are analysed, starting from an envisioned future based on a set of chosen targets, and then specific activities are planned, step-by-step, backwards from that vision to the current time.

- **Develop specific recommendations for different sectors**:
  Formulate recommendations for different target groups based on the integrated results (targeted communication). Make results of sector-specific modelling available to the related target groups; e.g. hydrological modelling for water managers.

- **Facilitate development processes:**
  Identify stakeholders and their interests, and start a dialogue among them. This often includes capacity building.

- **Provide decision making tools:**
  Decision support systems (DSS) use the developed models and make them available for stakeholders through user interfaces combined with knowledge transfer and capacity development.

These elements usually are combined: well-informed advice is based on, and combined with, scenario development. Local experts, government and politicians are supported in making decisions, for example, regarding coastal zone management, or the shaping of the landscape making use of a database and models on precipitations, groundwater levels, absorption capacity of the soil, GHG emissions, carbon stock, biodiversity, or regional socio-economics. More information on this can be found in Chapter 5.

Examples of Decision Support Systems (DSS)
The following are three different decision support tools designed for three very different contexts:

Siberia: large-scale agricultural production in the steppe region. The DSS was designed as a user-friendly simplified model (in excel-format) that will be provided to farmers as an instrument to enable them to calculate economic effects resulting from change of soil cultivation methods. The farm models were constructed to calculate profitability of reduced tillage in the Kulunda steppe in southern Siberia/ Altai Krai. The defined farm models cover three technologies: (i) intensive conventional tillage cultivation; (ii) minimum tillage cultivation and (iii) no-till technologies. Two types of crop rotation common under those technologies are used in the models. In the conventional/ old tillage system, wheat cultivation and fallow after two years of wheat planting is combined with intensive tillage. In the cases of minimum tillage and no-till, a crop rotation of wheat, then peas followed by sunflower was introduced. The models also consider depreciation and interest rate costs for both imported and Russian machinery. Finally, farm models are applied for various arable land areas (500 ha, 5,000 ha and 15,000 ha).

Southern Africa: small- and medium-scale production in semi-arid areas. A DSS that contributes towards sustainable land management was designed specifically with low requirements regarding internet access, software licenses and computing power. The system contains a browser that integrates all features into one interface. Furthermore, a special distribution of the Geographic Information System SAGA (System for Automated Geoscientific Analyses) is part of the DSS. With SAGA, it is possible not only to view, but also to interact with, a variety of spatial datasets and digital maps. The digital maps can also be used by stakeholders and policy-makers to inform and back up decision-making.

Tarim Basin/ N-W China: large-scale production in an area of extreme aridity. Here the DSS is an indicator-based tool (Figure 6.8) designed to support stakeholders and to train Chinese students to assess possible consequences of actions within the river basin. Different kinds of indicators are distinguished:

Input:
- socio-economic indicators;
- management indicators;
- climate scenarios and the consequent inflow into the Tarim – including evapotranspiration;
- initial grids (spatial units) for groundwater, salinity status and land use.

This leads to an Output of:
- ecosystem Services (ESS) indicators;
- results for salinity status and land use distribution.

The user can choose between four possible inflows to the Tarim River, depending on the four climate scenarios. The inflow into the Tarim represents the basis for the calculations in the DSS. The possible development of socio-economic indicators can be entered for the respective years. As default values, developments in prices for the years 2012, 2030 and 2050 are set. In the next step of the input section up to ten management measures for the Tarim River Basin can be planned and adjusted directly on the integrated grid based land use map. Each cell of the grid can be changed to any kind of land use, for example cotton production, forest, or waste land, as long as the corresponding requirements are fulfilled (e.g. no cotton fields in highly saline areas). In a final step, objectives can be chosen (definition of goals) and indicators can be given different 'weights' by the user. For this purpose, the DSS provides a list of the ESS (ecosystem services) indicators for each sub-region on which the evaluation of the management measures is based.

As an output for each management measure, the impact on the ESS indicators for each year between the 1st and 3rd planning years are calculated and illustrated in tabular form, graphically and with the help of maps. Based on these results and the objectives assigned to the ESS indicators by the user, an achievement level with a utility value between 0 and 1 is calculated, indicating to what extent the objectives have been achieved with the respective measure.

6.2 Impact – the role of research projects within the region and beyond

Implementation-oriented research has to perform the balancing act of doing 'excellent research' in scientific terms while producing useful results for, and often with, practitioners and decision-makers on the ground. Under present framework conditions of separated scientific disciplines and separated administrative sectors this is not easily done. Therefore, implementation-oriented, inter- and transdisciplinary research at present continues to co-exist with many compromises. The following section illustrates some possible ways of how research can have an impact on the practice of sustainable land management – and where the limitations lie.

6.2.1 Coming from the outside

A public funded research project does not depend economically on the fruits of land use or other vested interests in the research region. Its only responsibility is to produce sound scientific results and – in implementation-oriented SLM programmes – to make use of those results to support SLM implementation. This independence opens the possibility of research projects working as a mediator and facilitator for local land users and other stakeholders. Researchers have a certain status that they can capitalise

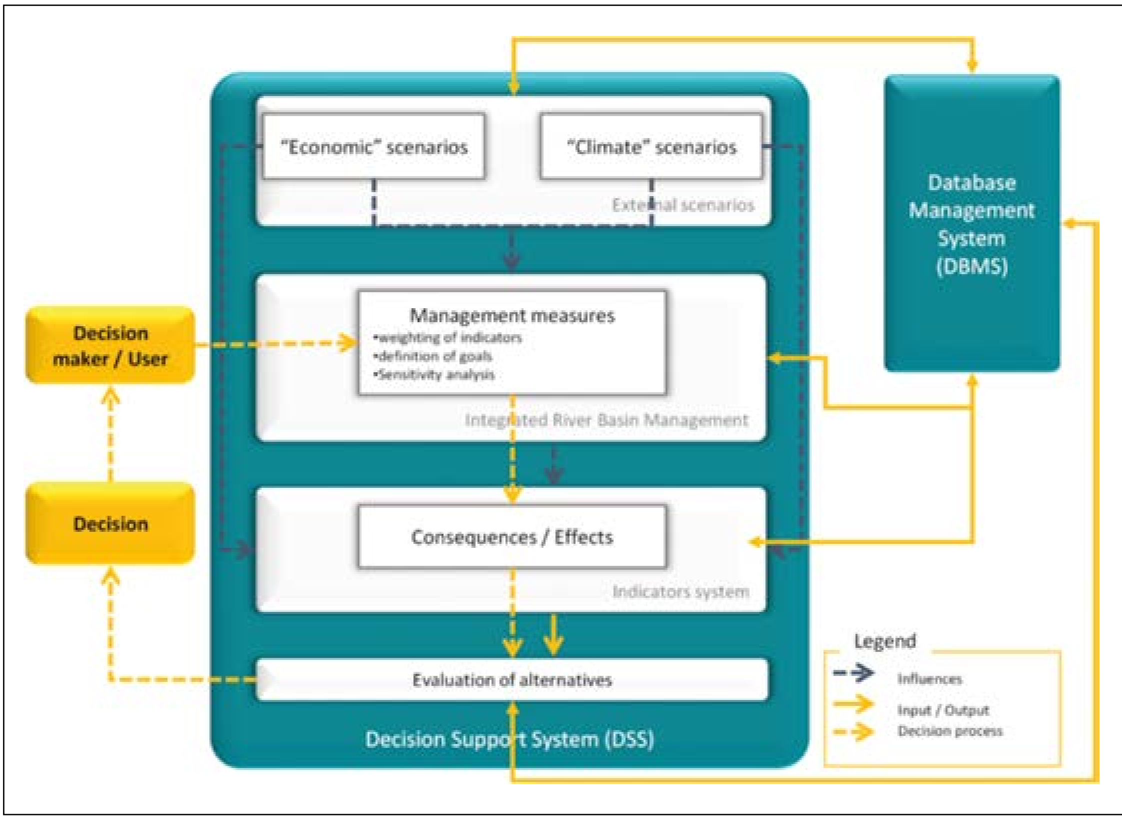


Figure 6.8: Schematic system architecture of the DSS, developed for the Tarim Basin, N-W China for large-scale production in an area of extreme aridity. The scheme demonstrates the most important relationships and the desired order of actions (Marie Hinnethal, further information see: Rumbaur et al 2014 and 2015 and Disse et al 2016).

upon: this is derived from credibility when providing data and information as well as recommendations and tools for action. In longer-term engagement in a region the position of researchers can change from being independent observers into actors within the region. This is especially the case when researchers are asked by local stakeholders to contribute to on-going development and decision-making processes. With regard to being implementation-oriented this might be considered a success. With regard to the role and professional image of many (even most) scientists, this can be a challenge.

An obvious strategy to support the implementation and use of research results during and especially after a research project is to partner with a local organisation, for example an NGO or a development agency that is well-established in the region. This strategy has the additional advantage for the researchers of working with an organisation that has experience locally, and that can help them to adapt to its specific context (language, cultural customs and making contacts). On the other hand, in the public perception scientists partly lose their image of being independent and run the risk of being identified with those partner organisations and their objectives and ambitions.

Here, especially, open communication and transparency about the research projects role is needed and may be the key to success. Researchers can be independent in terms of having no stake in regional decision-making or power relations. However, they can play an influential role in the region and should be aware of it. In SLM research, a possible starting point for defining one's own position could be reference to international goals and processes: for example the three UN conventions related to climate, biodiversity and land degradation, as well as to the UN's Sustainable Development Goals. Working within the framework of these UN conventions gives researchers orientation with respect to goals and targets, and at the same time opens space for independence versus vested interests of individual groups.

6.2.2 Initiating and facilitating dialogue

Transdisciplinary research often provides a platform for stakeholders to reflect their situation, especially among people who do not usually come together on a regular basis. In workshops, field days and other events, research projects offer opportunities to meet, facilitate dialogue and interaction, and provide people with information and tools to reach joint solutions. These multi-stakeholder dialogues connect communities such as:

- research and education;
- decision-makers and public sector (provision of government services);
- development agencies;
- civil society (including NGOs, lobby groups etc; and
- land users/ representatives of associations and cooperatives.

Bringing together the actors relevant for land management in a region, and building common ground among them, based on mutual trust, is an important precondition for later joint action. This can be initiated by research projects. But it is crucial for the longer-term success of such initiatives to organize and stimulate continuity of personal meetings and dialogues. For this, an organizer and facilitator is needed – one who takes over from the researchers long before the project ends. Some of the approaches used within such processes are made available in form of a manual or toolbox for further use in the region. This is especially welcome when methods are newly introduced. These topics are discussed in more detail in Chapter 5 and Part 2.

Graphic recording to support joint understanding
Graphic recording or 'visualisation' is well-suited to achieve and record an overview of different aspects of land use and climate change, different perspectives of involved stakeholders on land use as well as discussion results (Figure 6.9). During a joint workshop of scientists and non-scientific stakeholders, a specialist can visualise discussions and inputs on a map combining images (e.g. cartoons) and words. With it, a kind of joint 'language' can be found. This method can readily fit into documentation of workshops results.

6.2.3 Long-term impact in the region

One of the key targets of implementation-oriented research is to support adoption of improved land use practices and other innovations in the region. This, of course, is a considerable challenge for research within a limited time period of usually not more than 3 to 5 years. Suitable methods for local stakeholder involvement and implementation-oriented work are important, but can be limited by challenges of existing structures and power relations that have other priorities than sustainable development.

Preferably, research projects can build on long-term collaboration between universities and institutions in the region, which are involved in the research programme, and can continue after the end of a particular project. In some cases, projects strive to organize follow-up initiatives that pick up where the on-going projects have left off. But more enduring and thus central elements for long-term impact are the institutions and organisation that have been project partners or were otherwise involved in the research: they have the opportunity to incorporate some of the research results in their future work and take it forward. Test sites for experiments and demonstration can often remain in place and continue to be managed by project partners which can include farmers as well as universities, and other institutions.

In some cases, research results are taken up within official planning procedures. This use of results is difficult to plan. It closely depends on talking about the right 'thing' (topic/ issue) at the right time. To make room for adoption, it is essential to build contacts with a wide spectrum of potential users and to look for windows of opportunity to feed results into an on-going or new planning process. Such a window, for example, could be the development of a 10-year plan for a river basin. The following two examples illustrate how long-term impact can be institutionalized and how results of a structured stakeholder process can be taken up in official planning.

Installing a River Basin Information Centre
For those who want to know more about the Vu Gia Thu Bon river basin in central Vietnam, the River Basin Information Centre is a good address. The centre was initiated and developed in cooperation with the Vietnam Academy for Water Resources, at Da Nang City. It hosts the open source River Basin Information System (RBIS) which integrates all data and results from ongoing research. It took very considerable effort and time to make results accessible in an understandable format. The 'River Basin Information System' is also available online. The system can be maintained without additional costs, so longer-term continuation and sustainability becomes more likely. The existing data and information are open source and can be updated by scientists and professionals who work in the region; e.g. PhD and MSc students conducting research at the Vietnam Academy for Water Resources (see Approach 'VGTB information centre' page 275 and Chapter 5 page 114)

Uptake of results in regional planning procedures
A regional plan developed for the North Sea coast of Germany provides the framework for regional spatial planning for the next 10 years (Figure 6.10). Long-term planning in this region is of particular importance in relation to climate change, and to the fact that the land is close to, and often below, sea level. The regional plan emphasises that, already, changes in precipitation and the amount of water runoff are observable and are leading to pressures on the existing drainage system that keeps the ground water levels below the surface in the low elevated areas. The regional planning authority of the county is meeting this challenge and has designated water retention areas – taking up recommendations

Figure 6.9: Graphic recording from a stakeholder workshop in Germany (detail from a larger map) with focus on 'Sustainable land management against the background of climate change – a cross-sectorial examination'. From left to right: implementation is depending on societal acceptance, cost and benefits, and interdependencies; management ideas are inner urban development (Innenentwicklung, see Technology 'Inner urban development' page 199), flood protection (Hochwasserschutz), and changes in forest management (Änderung Waldbauvarianten); some of which are implemented already but further activities are needed, e.g. to mitigate loss of biodiversity. (Jonas Kramer, Visual Facilitators)

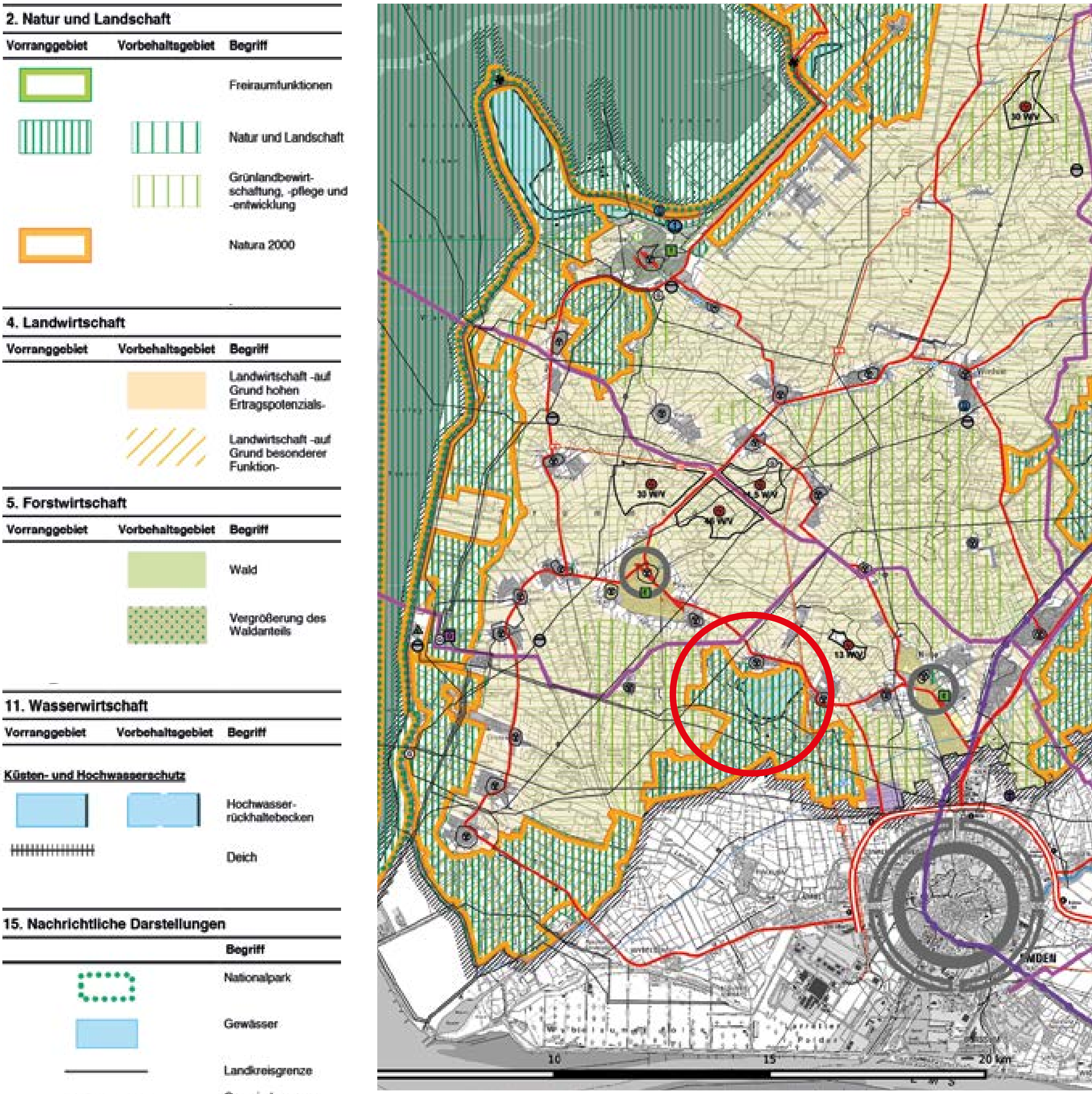


Figure 6.10: The Freepsumer Meer, northern Germany (red circle) has been designated as water retention area to adapt to negative impacts of climate change. This is the result from the scenario developed together with stakeholders. Different land uses are combined: Natura 2000 protection areas (orange outline), water retention areas (light blue), grassland (green outline with vertical lines), agricultural use (beige). The North Sea is dark grey. (New official regional plan Gemeinde Aurich (2015), http://www.landkreis-aurich.de/4243.html)

from participatory scenario development facilitated by researchers (see Approach 'Stakeholder participation' page 223 and Technology 'Polders to improve water management' page 215). Following the recommendations of the researchers the regional plan states that the establishment of water retention areas is instrumental in initiating development towards more long-term regional planning and management. Through these measures it may become possible to successfully tackle impacts of climate change beyond the 10-year time frame of the current regional plan.

The participatory scenario development contributed to minimising conflicts in land management and maximising synergies between different kinds of land use. It was instrumental in developing community-based sustainable and adaptive land management strategies that have been integrated in the amended regional plan of the country (see Chapter 2 page 70).

6.3 Framework conditions for implementation-oriented research: flexible and long-term

6.3.1 Greater need for flexibility

Implementation-oriented research, particularly in the area of sustainable land management is highly complex. Several disciplines from natural and social sciences, as well as the humanities, need to cooperate. Stakeholders from land management practice need to be able to bring in their ideas, experiences and needs for alternative measures and solutions. These ideas and inputs need adequate platforms for communication. Various land management technologies need testing with the chance and virtue of succeeding or equally making mistakes. From this follows the need for a stepwise approach to process and project planning. Outcomes/results of each step in the research process and the interaction with non-scientific stakeholders cannot easily be foreseen. During a 5-year research project many factors can change that cannot reasonably be forecast when writing a project proposal – a process that may take place one or two (or more) years ahead of project start-up. Flexibility to react to external changes, therefore, is crucial in implementation-oriented research design and implementation. New questions or problems arise that have to be researched, political or administrative changes in structures and people occur, weather conditions alter – and so on. Frameworks for research funding as well as project management have to take this into account.

6.3.2 Co-production of knowledge needs more ad hoc funding

Another need for more flexibility concerns the funding of implementation activities. Project proposals should leave room for science-based innovation and co-production of knowledge and solutions with stakeholders. Many ideas may arise from new information and changes of circumstances. To be able to follow up on these, it would be of great value if, for the last two years of strongly implementation-oriented projects, ad hoc funding was available. Funding agencies should provide the possibility of applying for additional funding for the implementation of innovative activities and/or support the development of co-operation with implementation partners by using their own funds, or facilitating the sourcing of other funding streams.

6.3.3 Different worlds of science and practice

A great challenge lies in the different 'logics' of the worlds of science and practice. Decisions, especially in the worlds of practice, are not simply evidence-based. They also largely depend on opportunities, framework conditions, vested interests, and power. And what is relevant from a scientific point of view might be a side-issue for some of the local stakeholder groups. Also, timelines of science and practice can be very different. Politicians and companies often want answers immediately and with a high level of probability. Yet in most cases, science often cannot provide them off-the-shelf, and research projects usually are designed for 3 to 5 year periods. Only well-designed communication strategies may help to bridge those gaps. What is needed here, is the provision of interim and preliminary results to stakeholders on a regular basis; something scientists often hesitate to do.

6.3.4 Suitable timelines

Even a five-year timeframe is often not enough to produce reliable results. Setting up a large international collaborative research project takes up most of the first year. PhD students thus do not start their work on the day after the grant agreement is signed. They need to set up their own work, in sometimes difficult and unfamiliar conditions when working in a foreign country in international research cooperation projects.

Field experiments and field research in sustainable land management are closely dependent on the seasons, and the vagaries of the climate in those seasons. Suitable timelines need to be established and experiments repeated to compare and verify results. In natural science, fieldwork data can be distorted because of variabilities between and among years and/or extreme weather events. Under these conditions it is expected of the PhD candidates that they should work with local stakeholders, with scientists from other disciplines, in some cases learn the local language and social habits, and publish in both scientific and non-scientific media. To be able to deal with all these demands, most PhDs need more than 3 years. Longer timeframes and contracts for PhD students therefore are needed in programmes where stakeholders from land management practice are involved and implementation 'on the ground' should be supported. This would also have another advantage: those who have done the research might be available for longer within a five (or more) year project and be able to better support the development of results and recommendations based on their work.

Many activities in research and practice only bear fruit if they are carried out longer term: 10 years and more to accommodate changing conditions. Change takes time, especially in complex systems. Working together effectively across the communities of science and practice and across sectors and disciplines needs trust, which does not develop overnight. Long-term involvement is key to success, as problems and possible solutions are continuously evolving. Thus, innovation should be seen less as a finished product but more as a process of development and adaptation.

Conclusions

In this chapter we have looked at the complex challenges surrounding sustainable land management. Land, as demonstrated, is 'multi-dimensional' in various different ways. And when developing strategies and solutions multiple perspectives and interrelations have to be taken into account. The conclusions can be summarised as follows:

Integrated methods and solutions

Scientific methods of integrated modelling and assessment enable researchers to live up to the challenge of the multi-dimensional character of land management (multi-functional, multi-scale, multi-time, multi-sectorial, multi-tenurial and multi-stakeholder). They are based on systematic collection and analysis of data from natural sciences, social sciences and humanities. Interdependencies causing synergies and trade-offs of management practices within the complex soil-vegetation-water-climate nexus are taken into account across different scales of space and time. This is a precondition for developing solutions and recommendations that are more robust and sustainable than developing singular measures within just one sector and focusing on just one problem.

Understanding local – landscape interactions

Most land management practices are designed with a focus on specific local impacts. Scientific methods allow the assessment of off-site effects of those practices, and design land management strategies on larger scales that take local – landscape interdependencies into account. This is most obvious when looking at upstream/ downstream conflicts within river basins. But it is necessary for all aspects of the soil-vegetation-water-climate nexus that are connected – while spread across different scales of space.

Looking into the future

Model-based scenario development provides researchers and practitioners with the opportunity to assess impacts of different land management options on soil productivity, water availability, biodiversity, carbon sequestration, livelihoods, economy etc. It provides the opportunity to combine land use and climate change scenarios, and to project future developments, thus giving early warning about upcoming challenges and helping to develop adaptation strategies.

Joint understanding of complexity

Joint development and use of models and scenarios by researchers from different disciplines and land management practitioners of different sectors has benefits for all involved. It supports understanding and appreciating of the complexity of land management systems, and it keeps models and scenarios grounded in the reality of practitioners and decision-makers. This provides a suitable basis for co-production of knowledge and solutions.

Dialogue platforms for coordinated action

Implementation-oriented research can offer a platform for dialogue that is otherwise often missing as there is no single administrative responsibility for land and land management. Bringing different stakeholder groups together, and developing a joint understanding of the problems at hand and the future challenges, stimulates awareness in decision-makers of the need for integrated planning and coordinated joint action. Researchers can enact the role of an independent facilitator in those processes. They provide information and recommendations from a 'neutral' position of credibility without vested interests.

Products and long-term impacts

For longer-lasting impact in a study region a diversity of products should be developed through research. Models can be simplified and equipped with a user interface to serve as decision support systems in future planning processes. To support uptake of research results, data must be organized in open access data bases and results should be offered at the right time and in a form suitable for the respective target groups. Building partnerships within the region is a successful strategy to support implementation processes and their continuation beyond single, time-bound, research projects.

Working together and adapting constantly

For successful implementation-oriented research in sustainable land management, collaboration and communication are key factors. Because of the multi-character of land no one discipline, sector or stakeholder can develop sustainable solutions alone. This needs to be reflected in the set-up of research projects, implementation projects and planning processes. That includes the flexibility to adapt to new knowledge or changes of circumstances that could not have been foreseen in the set-up stages of such processes.

Think and act long-term

All research-practice collaboration takes time. Time to build trust. Time to understand complexity as well as each other. Time to develop and test solutions. Time for setting up experiments, collection of field data and analyses. Time for adapting and calibrating models and developing scenarios. Time to implement and distribute what has been successfully tested. Time to change unsuitable structures and overcome habits. Three to five years are seldom enough for the multiple tasks of implementation-oriented research. Establishing long-term relationships and truly engaging within a region beyond single projects and programmes is crucial for meaningful research successfully put into practice.

CHAPTER 7

Conclusions and key messages

The twelve research projects on which this book is based cover regions of highly diverse socio-economic contexts, land use types and landscapes. They embrace a wide variety of interrelated and interconnected land use and land management challenges. In the following we try to summarize what has been learned and provide key insights from this research. We hope that the reader will find these reflections stimulating and thought-provoking, attracting critique, and hopefully and particularly, leading to better directed research and implementation in sustainable land management.

The basis of land management

Ecosystems are the foundation of our existence. Nowhere is this more obvious than in land use and land management. Production systems on land – no matter whether agricultural production systems or others like within urban areas – have often been intensified until the underlying natural support systems, the ecosystems, are damaged to a degree that the quality of the production, its outputs and the environment suffer. The consequences of land degradation are decreasing quantity and quality of plant yields, the need for increasing external inputs to maintain yield levels – and impoverished quality of life in cities and other landscapes. These problems are aggravated because pressure on the land related to production of food, non-food products, and infrastructure is growing due to population increase, lifestyle changes and in many cases, climate change. It is becoming clear in many regions that 'business-as-usual' intensification of land use is no longer an option.

This is where sustainable land management (SLM) comes into play. One of the central strategies that has been developed and presented in this book is 'sustainable intensification' on existing agricultural land: increasing or stabilizing production while preventing damage to the underlying ecosystems. Thus, SLM is able to make use of the ecosystem's full production potential but at the same time respecting its boundaries.

➔ The examples in this book confirm that preservation of ecosystems and the provision of their services can be accomplished within production systems (land sharing), and outside of them through the intensification on productive land – while leaving other land out of production (land sparing). The question is not 'either / or'. It rather is how to integrate both within the available space of this planet.

Flux station to measure CO_2 and CH_4 emissions in Siberia. (Elisa Fleischer)

Dried up river in the São Francisco river basin. (Maike Guschal)

➔ To do so, sustainable land management has to take several societal claims on land into account:

- Production: Fulfilling human needs for food, water and other land-based products as well as for settlements and infrastructure.
- Sustaining ecosystem functions: Preventing further depletion or degradation of natural resources of soil and soil biota, water, vegetation and animal life and thus keeping our life base and natural resources intact and resilient (see UNCCD and CBD).
- Climate change mitigation and adaptation: Preserving the capacity of ecosystems to mitigate, as well as adapt to climate change (see UNFCCC).
- Preservation of nature and biodiversity: Reducing pressure to convert natural and semi-natural areas into arable land, which reduces biodiversity (see CBD).

Sustainable Land Management and the role of research

These multiple claims on, and dimensions of, land need to be addressed by sustainable land management. As illustrated in this book related research and practice should be based on a:

- **nexus perspective**, taking into account the whole system with its interdependencies between soil and soil biota, water, climate, vegetation, animals and people.
- **multi-scale perspective**, taking into account interactions of land use and natural systems on and between different scales, from local to landscape to national to global.
- **multi-time perspective**, taking into account short-, medium-, and long-term impacts and feedback from land management options.
- **multi-stakeholder perspective**, taking into account interests of people living on, and using land in, different parts of a landscape, different sectors depending on, and using land, different levels of decision-making and governance related to land management, and different sources of knowledge – scientific and non-scientific.

➔ Individual land users, planners and decision-makers seldom have the capacity to consider all these multiple dimensions and interdependencies without the support of research. Researchers have tools to give insight into such dimensions and interactions and can provide a better informed and broader basis for land management decisions. Especially useful in this respect are models and scenarios that are designed to integrate those multiple dimensions of land, test impacts of different land management options, and identify synergies and trade-offs of the options.

➔ Decision-makers at all levels should make better use of the support that research can provide:

- Integrating 'local' land use into landscape planning and management interventions (e.g. within a watershed) by using synergies between different interventions and avoiding negative impacts of local interventions in other areas (e.g. downstream).
- Considering short and long-term impacts and taking them into account in planning and decision-making.
- Involving research to explore combined impacts of land use and climate change at local and regional (landscape) level, as well as over short and long time periods and under different climate and land management scenarios.

➔ Because of the multiple dimensions of land, many different stakeholders need to be involved in developing solutions and strategies for sustainable land management. In such multi-stakeholder processes researchers can play an important role by initiating them and supporting a joint learning process among all involved.

For example: addressing food security, climate change and biodiversity preservation needs an integrated approach that deals with the complex interactions and interdependencies within and between the human and natural environment, involving all relevant stakeholders in joint planning and decision-making.

At the local level, on one plot, often single or few land users are involved in decision-making. But at landscape level, planning depends on many stakeholders, their interaction and their claims and demands.

Synergies and trade-offs in SLM

Land use and land management can cause loss of biodiversity, climate change and land degradation, but can also be a possible means of combating degradation and improving adaptation to, and mitigation of climate change. This book is full of examples of how synergies and co-benefits in SLM have been made use of for land management practices in different contexts. It is possible to contribute to the land degradation neutrality goal of the UNCCD, and even improve resilience and health of land-based ecosystems, while at the same time satisfying people's needs for food, fibre, fodder, fuel and clean water. Sustainable land management can help to improve the capacity of ecosystems, including agricultural production systems, to respond to changing societal claims and support mitigation and adaption to change – be it climatic, environmental or socio-economic.

Soybean field under no till in the Mato Grosso, Brazil. (Stefan Hohnwald)

Flooded wetlands, Seronga, Botswana. (Lars Landschreiber)

In this respect some principles of sustainable land management, as demonstrated by the research covered by this book, stand out:

- ➔ Sustaining or improving soil organic matter and carbon (SOM/ SOC) has positive effects on soil fertility/ nutrient availability, soil biodiversity, water-holding capacity and thus water availability, and carbon sequestration in almost every context.
- ➔ Maintaining soil cover prevents soil erosion by wind and water, decreases surface evaporation, improves water infiltration, and decreases mineralisation of soil organic matter, while reducing CO_2 emissions.
- ➔ Optimizing the allocation of different land uses within a landscape, and adapting land use and land management to local environmental conditions, taking into account available soil, water and climate, for example in the choice of crop as well as in the choice of land management practices.
- ➔ Integrating or keeping structural landscape elements (riparian forests, flower strips, hedges, trees, earth bunds, terraces, mini reservoirs) within the production systems prevents water runoff, soil erosion, increases water availability, storage capacity and quality, supports integrated pest management and preservation of biodiversity above (through corridors) and below ground.
- ➔ Combining measures is essential: applying not just one land management measure at a time but combating trade-offs and developing win-win strategies: in no-tillage agriculture, increasing weed burdens can be remedied by combining no-tillage with crop rotation and precision application of herbicides.
- ➔ Focusing on system resilience and disaster risk reduction, instead of maximising outputs, is a possible way out of the long-standing ecology versus economy conflict. For example: orienting production at stable, instead of maximum, yields becomes especially important in times of a changing and less predictable climate – as well as with unreliable markets. Other successful strategies focus on high value crops and/or income generation along the whole value chain. Diversification in production systems, landscapes ('mosaics') and income generation is a proven strategy to improve system resilience.

However there are also trade-offs between different societal claims on land such as food security, income/ livelihoods, settlements and infrastructure, climate change mitigation and adaptation, energy production, water availability and quality, nature and biodiversity protection and so on. And there may be trade-offs between different land users and different scales of time and space. The underlying questions of these trade-offs are: who benefits, who pays, when, and what can be done?

Four interlinked basic trade-offs stand out here:

- **Production, income, and livelihoods versus ecosystem preservation**:
  Even though functioning ecosystems, be they natural, semi-natural or production-oriented, are the bases for improved production, sustainable income and livelihood, there can be a conflict between economic interests and the preservation or improvement of ecosystems when balancing economic, ecological, social and cultural costs and benefits. For example, in some contexts a less intensive or less degrading management of a production system can improve biodiversity but lead to losses in yield and income. This is most obvious where natural conditions for agricultural production (soil, water, and climate) are advantageous/ favourable and degradation has not yet taken place. It is also an underlying conflict in cases of overexploitation of ecosystems (e.g. forests) or land conversion from natural or semi-natural land into cropland or settlements.

- **Long-term versus short-term costs and benefits, for example:**
  Some SLM practices need higher investments (workload, financing) in the short term but only have yield benefits and returns to that investment in the long run (e.g. improvement of soil fertility takes time; preventing yield losses through addressing land degradation with structures pays off only in the long term).

- **On-site versus off-site effects, for example:**
  SLM practices often have positive effects beyond the direct area of their implementation. This is especially the case when it comes to water quality and quantity. In typical upstream – downstream situations, investments in the upper river catchment – or their lack – come with little or no effects on water availability or quality for the upstream water users, whereas downstream effects can be considerable. Preventing damage and risks downstream like flooding, water shortage or decreased water quality through upstream land management is seldom valued economically by the downstream users. In other words upstream users are not compensated or rewarded for the services they provide downstream. People investing in sustainable/ long-term effective land and water management measures are often not the same as those who benefit. On the other hand the lack of investment upstream may cause damage downstream that are not compensated by the responsible parties upstream. It is the case that for most management measures at landscape level, some people receive more benefits – or incur greater costs – than others.

Measuring water infiltration, Mato Grosso, Brazil. (Stefan Hohnwald)

The Tarim river basin. (Patrick Keilholz)

- **Private versus public goods, for example:**
  Land degradation often has the characteristics of the so-called 'Tragedy of the Commons'. When the depletion of the common resource – 'land' – has benefits for individual users without immediate repercussions on them for the degradation they cause, there is little incentive to them for its preservation. This is the case particularly in situations where traditional or modern governance systems are dysfunctional. Balancing the costs and benefits of land management demands close cooperation and mutual responsibility of all stakeholders.

A basic strategy of research for SLM is to identify and make use of synergies while minimizing trade-offs. An example of a typical combination of synergies and trade-offs is the extensification of land use in grasslands, wetlands and forests. This practice has benefits for climate change mitigation, climate change adaptation as well as biodiversity preservation. The central trade-off is the decrease in production and thus of income from those areas.

➔ Research should identify and describe those synergies and trade-offs. Unclear trade-offs, costs and benefits, winners and losers at the local and landscape level may lead to conflicts. Trade-offs need to be clearly identified, and assessed. They take different forms in different contexts. Thus there are no universally applicable best practice solutions. Land management options based on the above listed principles need to be adapted and optimized within their specific regional and local context.

➔ Making use of synergies and finding solutions that balance different societal interests is a task for policy-making and governance. To achieve successful SLM implementation, trade-offs need to be addressed by adequate framework conditions, negotiated between the different stakeholders, and compensated in cases of individual losses and societal benefits or other winner-loser situations. For example, impacts of land management in upstream zones on downstream areas are often not assessed and thus usually not compensated – or sanctioned in case of damage. Even though talk about payment of ecosystem services has been ongoing for some time now, payment to good upstream land management practitioners by downstream users is practically non-existent. This is partly due to lack of the assessment of impacts of local land management practices and its costs and benefits downstream. Here, research has a key role to play, but also policy and administration have to adapt governance frameworks and implement measures accordingly.

Implementation-oriented research

To have an impact on sustainable land management, researchers, decision-makers, and land users need to work together.

In the complex and continuously changing field of sustainable land management, inter- and transdisciplinary, implementation-oriented research can deliver results that people from land management practice can relate to. Making sense of this research largely depends on integration across disciplines as well as integration of knowledge and people from both science and practice.

The following key tasks have been identified for implementation-oriented research:

- **Empowering land users and decision makers**
  Implementation-oriented research identifies and closes knowledge gaps in research and practice and supports implementation of solutions jointly with SLM practitioners (land users/managers). It enables more holistic perspectives on land management and provides instruments and tools to identify viable solutions. It presents the larger picture in terms of system complexity, space and time, as a context for suitable land management options. Thus it supports implementers to take evidence-based decisions.

- **Working cooperatively and on equal terms**
  Although collaboration is being realized in hundreds of research programmes there is still an awkward relationship between scientists and non-scientists. Integrating different kinds of knowledge is a difficult task and needs further improvement. A key ingredient of successful research – practice interaction is working cooperatively on equal terms, with mutual respect for each other's experience and expertise.

- **Developing joint understanding of complexity**
  Between researchers from different disciplines as well as with non-scientists, understanding complexity of land and making it accessible, is key to producing useful knowledge and solutions for SLM. This presents a considerable challenge, both methodologically and for communication in the process of working together. To achieve this understanding, methods and cooperation processes need to be improved, and time needs to be allocated for joint learning by researchers as well as partners in SLM practice.

Silver-washed Fritillary. (Sarah Weking)

Intercropping in rubber plantations. (Manuel Krauss)

- **Flexibility and adaptive management of research processes**
  Working together and adapting constantly is characteristic of implementation-oriented research. Flexibility is needed in many respects: time-frames, funding schemes, and methods. Because the context in which the research is carried out is constantly changing, research projects and programmes are required to regularly check their objectives, to adapt to current changes and unforeseen events, or to take on new ideas instead of carrying out a pre-ordained plan.

- **Think and act in the long-term**
  All of the above mentioned activities take time, inevitably more than originally anticipated. Field research in unpredictable weather conditions, monitoring within changing systems, integration of different kinds of knowledge, communication among people from different contexts, and especially supporting implementation and change of land management require long-term perspectives and engagement. For research this means involvement in the region long beyond the normal 3 to 5 year project period, in order to follow-up and build on existing research and to develop continuation strategies for the use and implementation of research results.

➔ Implementation-oriented research has strong contributions to make to SLM. Methodologies and tools to do so are available, but still need further improvement and better integration into relevant organisations and institutions. Research needs to put more emphasis on solutions and their adoption in practice. It needs to move from producing knowledge about SLM to developing knowledge for SLM jointly with those who make use of it.

To develop this interface between research and implementation, it needs different framework conditions for this kind of research as well as for the implementation of improved SLM that emanates from it.

Framework conditions for implementation-oriented research

During the last few decades – especially since the Earth Summit in Rio 1992 – research, and research funding have taken up the challenge of contributing to sustainable development. Several steps have been taken in developing suitable research methods and tools. But there is still a long way to go to adapt the framework conditions for research and researchers to the requirements of implementation-oriented research.

The present frameworks and funding procedures are fundamentally still based on the traditional divide of basic (knowledge-oriented) research and applied (often technology-oriented) research. Another and growing field of implementation-oriented research for sustainable development has not yet received the same recognition. This third field needs suitable framework conditions in the science and science funding systems that are different from those that were designed for basic and applied research:

➔ **Flexibility**
Implementation-oriented research needs to adapt constantly to on-going changes to provide relevant knowledge, and to take advantage of opportunities that open up during the project. Funding procedures and management of research programmes need to reflect this need for flexibility. For example, research projects are still often asked to deliver a priori determinations of project outcomes, while in implementation-oriented programmes this is usually impossible – and can be counter-productive as too narrow a focus and inflexible management can lead to the loss of important findings.

➔ **Time-frames**
Time-frames for research programmes and projects need to be much more adaptable and longer-term. This includes pre-phases to jointly design a project with on-the–ground partners as is sometimes done (as in the follow-up call for the SLM programme) as well as post-project funding for the implementation of ideas that evolve during the project. Many activities in research and practice only bear fruit if they are carried out long-term. For implementation-oriented research in such complex contexts as SLM 10 years is much more realistic than 3-5 years.

➔ **Training**
Teaching methods for implementation-oriented research need to be integrated into the formal training of young scientists. This particularly concerns more open and learning-oriented methodologies, communication techniques, facilitation and other methods suitable to enable stakeholder analysis, stakeholder involvement and co-production of knowledge.

➔ **Incentives**
For implementation-oriented research, scientists need a better perspective for their own future: new career paths, their not-purely-scientific activities valued, reassurance that this kind of research will continue to be funded, and that the time invested into adopting the necessary skills will be worthwhile.

Grassland at the North Sea coast, Germany. (Hanna Timmermann)

Sheep herding in the Andremba area, Madagascar. (Tobias Feldt)

➔ **Supervision**
PhD candidates in complex inter- and transdisciplinary as well as implementation-oriented research projects need a supportive environment and active supervision to balance the challenge of this kind of research with their – usually monodisciplinary – tasks of completing their thesis.

➔ **Management/ coordination**
Highly qualified and experienced project coordinators are crucial for the integration of knowledge and experience across disciplines, and between scientists and non-scientists. They are needed for effective knowledge management and synthesis building from different kinds of knowledge. For the organisational management of projects, they need to be supported by project secretariats. In addition it should be standard procedure for implementation-oriented research to make use of the competence of experts for communication, facilitation, stakeholder analysis and involvement.

➔ **Partners**
Research funding also needs to provide incentives and financial means for implementation partners, for example budgets for testing new SLM options or coordinating implementation processes. Support should also be provided through inter-ministerial and cross-sector cooperation initiated by funders, for example between research funding and development aid, or diplomatic support of activities in the partner countries.

Framework conditions for SLM implementation

Land use and land management are, to a large extent, also governance issues. Balancing the different societal claims and needs related to land management is a political and societal task, especially whenever short-term or singular benefits stand against long-term sustainability.

Most of the current structures, institutions and administrations related to land management are not designed to provide that kind of governance – even if science starts more successfully to deliver information about social, political and institutional set-ups, vested economic interests or interconnections and trade-offs between individual interests and common goods.

Ideas and land management options developed by researchers sometimes meet hurdles in implementation because of socio-economic factors, e.g.:
- Lack of legislation and/or law enforcement
- Lack of science into policy
- Perverse subsidies/ incentives
- Population density
- Low level of education and knowledge
- Lack of access to financing
- Insecure or unclear land use or tenure, resulting in the loss of long-term perspectives
- Lack of cooperation among different administrative units and ministries.

It is not the role, nor in the power of research, to change such framework conditions into an enabling environment. But research results can have a stronger impact practice when the political and socio-economic structures are supportive of the necessary changes in land management.

This involves:
➔ Incorporating nexus-thinking and action in many levels of policy, planning, and decision-making. This requires better cross-sector cooperation, understanding and taking interdependencies of land management into account and developing corresponding strategies. The implementation of the UN 2030 agenda and the SDGs ask for exactly this kind of paradigm shift from sectorial and issue thinking to systems thinking.

➔ Taking on-site/ off-site effects of land management into account in planning activities as well as legislation or subsidies, while coordinating respective action across all scales.

➔ Creating incentives to compensate trade-offs of SLM (see limiting factors above). This includes subsidies as well as clarifying land use rights and providing long-term tenure security to make investments in SLM attractive. Such incentives are only effective if adapted to regional, and even local, conditions.

➔ Providing transparency regarding available data and information on land-related aspects for all stakeholders involved. Access to knowledge between research and practice needs to work in both directions: researchers providing their results to practitioners, and people and institutions in land management practice allowing researchers access to their data and knowledge.

➔ Securing long-term monitoring and experience-sharing, involving multiple actors, using local/ regional universities as independent knowledge managers, assuring high quality and accessibility for SLM information and as a remedy against ‘institutional amnesia’ (don’t re-invent the wheel every time!).

Water channels through the Taklamakan desert, China. (Patrick Keilholz)

Andremba village from a bird's eye view, Madagascar. (Katja Brinkmann)

Outlook

When looking ahead there are some additional tasks for stakeholders in science, science funding, land management, land governance and beyond to make more sense of SLM research:

Tasks for SLM practice and policy:

➔ Close the 'governance gap' concerning land management: improve and/or develop political and administrative structures that reflect the complexity of land management by cross-sectorial cooperation or new institutional set-ups. This would clarify the political and administrative responsibility for SLM, and help to minimize trade-offs between different sectors, and to balance different societal claims on land. It would also provide SLM researchers with adequate partners who can take up integrated and complex research results (e.g. make use of decision support systems based on integrated models).

➔ Openness and willingness to base decisions on evidence and long-term societal goals. This can be supported by providing platforms, establishing interface mechanisms and many other specific occasions for research to present and discuss results. Engage in stakeholder dialogues within research projects, and take their outcomes into account in land-related planning and decision-making.

Tasks for SLM research:

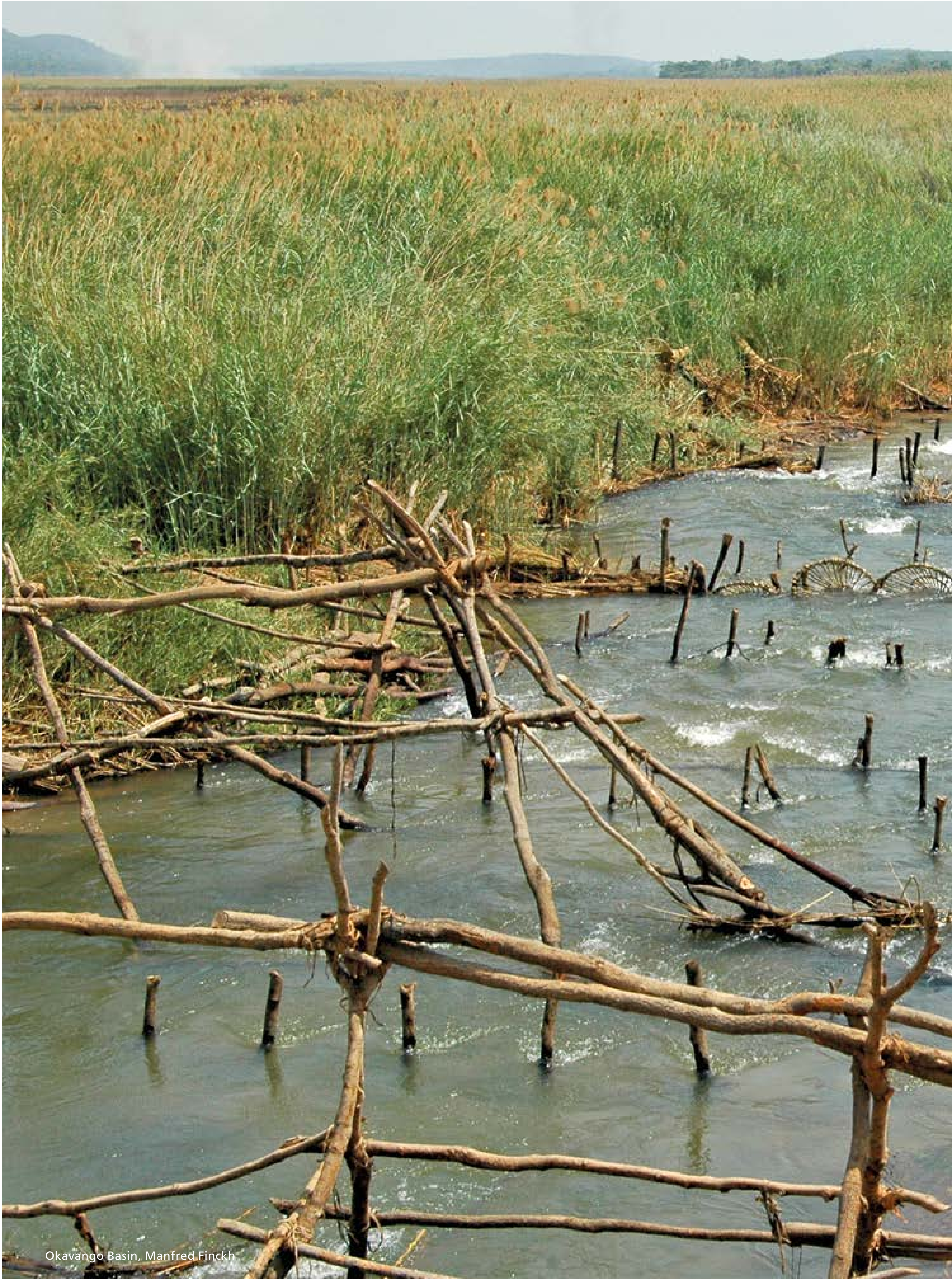
➔ Clarify 'ecosystem boundaries' – following the 'planetary boundaries' concept – in the sense of researching limits for the use intensity of land-based ecosystems necessary to avoid land and water degradation in different contexts. This includes research on economic and societal costs if these limits are not respected.

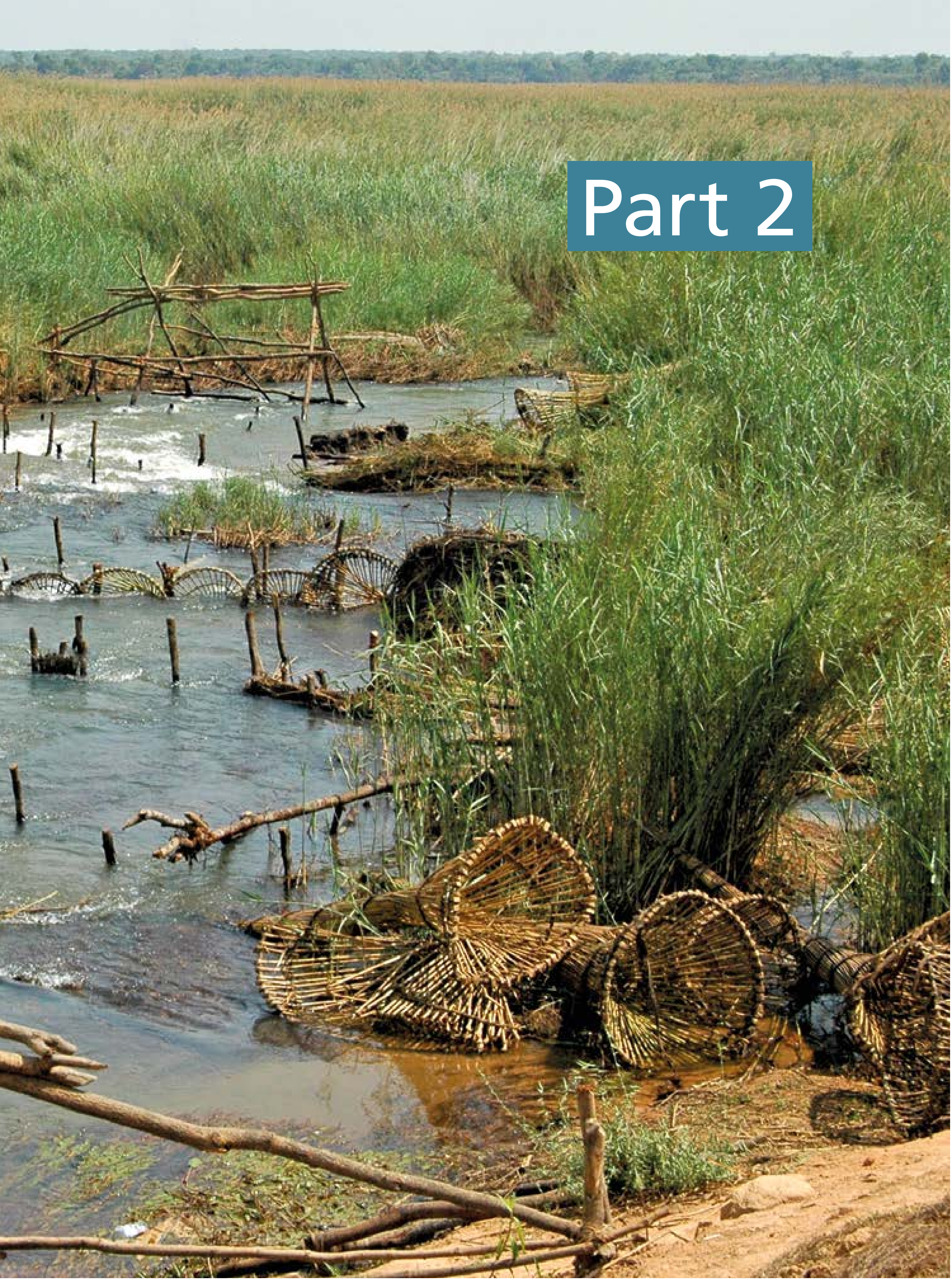
➔ Research socio-economic framework conditions for SLM implementation: this includes developing recommendations on how to close gaps in land governance (institutions, legislation, administrative procedures) and how to improve incentive structures for SLM. Therefore SLM research projects need to involve researchers from political science, economy, governance, jurisprudence, etc. to a much larger degree than it is currently the case.

Tasks for a wide group of people from research, research funding, governance and practice of land management:

➔ Raise awareness at all levels about interdependences around land, the importance of the related ecosystem services and our dependence on them for production, material, energy, air and water, recreation and cultural needs. This is a communication task for policy and education in which research can play an important role.

➔ All stakeholders involved in implementation-oriented SLM research need to grow into a new role in this collaboration: learn together, and from each other. Clarify and overcome the different expectations towards each other. Work together for the improvement of SLM. And create framework conditions in research and practice of SLM that enable all participating cooperation partners to do so.


Okavango Basin, Manfred Finckh



Part 2

PART 2

Case studies

Brazil, Pierson Barretto

Introduction

Part 2 comprises a selection of project related case studies. After a first glimpse of the overall research results from the 12 regional projects, a selection of the most practice oriented results – the 'technologies' and 'approaches' (introduced in Part 1) – are presented according to the familiar and standardized, WOCAT format for documenting and disseminating SLM. The documentation is supported by its carefully-structured and user-friendly database. Each case study consists of a series of sections: a description, technical specifications, implementation activities, costs, an overview of the natural and human environment, as well as an analysis of impacts, economics and adoption of the technology in the specific context. The majority of the technologies and approaches documented within the BMBF-SLM programme are presented in this book. However, there are others that can only be found in the database.

Linked to the written documentation of technologies and approaches are six 'instructional videos' or 'video clips' illustrating further details and data (see Table page 156). These videos not only provide SLM knowledge for sharing, but can also motivate farmers/ land users to replicate a particular SLM technology on their fields, and can stimulate projects and programmes to adopt a particular approach (see https://www.wocat.net/en/knowledge-base/slm-videos.html). All this data is based on authentic information from the field - to help in advocacy for evidence-based SLM.

Case studies

Brazil

China

Germany

* see video related to case study under https://www.wocat.net/en/knowledge-base/slm-videos.html

** the case study can only be found in the WOCAT database under https://www.wocat.net/en/knowledge-base.html; https://qcat.wocat.net/en/wocat. All case studies can also be found under the same link(s)

For more information on projects refer to Annex page 280.

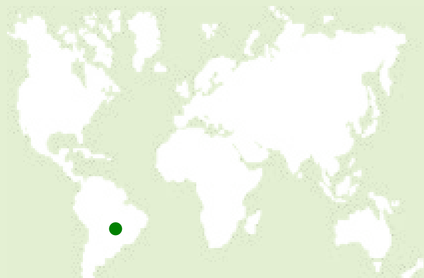
left: Experimental plots on a tropical agricultural soil (a ferrasol) after organic matter additions. (Photo: Malte Unger)
right: Sawdust of *peroba* and *cedrinho* (*Peroba jaune* and *Erisma uncinatum*, respectively). These are types of organic matter added to the soil. (Photo: Malte Unger)

Carbon-enrichment of tropical agricultural soil with organic matter

Brazil - Enriquecimento de carbono em solo de lavoura com matéria orgânica

Carbon-enrichment of tropical agricultural soils with locally available organic matter in the Cerrado agricultural landscape, Brazil.

In the Carbiocial Project viable land management strategies were explored to optimize the level of carbon in soil and water, helping to maintain and/or improve ecosystem functions, under changing climatic conditions in the Southern Amazon and the Brazilian Cerrado. In the framework of this project, on-farm experiments were performed to enrich tropical agricultural soils in the medium term, with different types of organic matter (OM). In the experiment the effect of different types of OM amendments on soil carbon and macro-nutrients (N, P, and K), soil physical properties (waterholding capacity) and crop yield (soy biomass and grain production) were assessed. The amendments applied are locally available, and are either free (being waste materials) or considered cost-efficient.
The objective of this on-going experiment is to compare the impact of (i) the quality and quantity of OM applied, (ii) and the application methods (directly on the soil surface or incorporation by harrow) on soil chemical and physical properties. It is hypothesised that the addition of OM can enhance crop yields and, potentially, soil biodiversity. The effects of the different OM types, amounts and application methods were evaluated after one, two and three years. From the results, the aim is to provide recommendations for the development of soil OM-enrichment schemes and carbon-friendly landscape management programs for farmers, using local resources.
The experiment was established on an area of about one hectare on a ferrasol (red latosol) at the Rio Engano Farm, in the municipality of Campo Verde, Mato Grosso State. The farm has a total area of ca. 1500 ha, 830 ha of which are cultivated with soybean and maize rotation, under a zero-tillage system, which is typical of many farms in this region. It is located in the Brazilian Cerrado (savanna) biome at about 685 m a.s.l. This biome covers 2 million km^2, which is 23% of the country area. It has a semi-humid climate with a pronounced dry season. The precipitation during the rainy season (September-April) varies between 800 and 2000 mm/year.
At the beginning of the experiment (February 2012), three different types of OM amendments were applied. They comprised (a) sugarcane filter cake (*Saccharum officinarum* from ethanol/sugar-production, (b) sawdust of *peroba* and *cedrinho* (*Peroba jaune* and *Erisma uncinatum*, respectively) and (c) coarse chips of *Eucalyptus sp.* Quantities applied were 0 (control), 6, 12 and 18 tonnes of each per hectare; using two methods: directly on the soil surface, and incorporated by harrow. There were three repetitions per treatment. The area was not fenced to allow the farmers to continue with their field routines on all plots. In February 2013, 2014 and 2015 soil samples were taken to analyze their chemical and physical properties. Soybean samples were also taken in February 2014 and 2015 to estimate biomass and grain production. From the initial results some conclusions can be drawn: 1) Organic amendment addition to ferrasols can significantly increase soil organic carbon, even in amounts as low as 6 t/ha. 2) Amendments should be reapplied every 2 years. 3) The amendment type and application method does not have a significant effect on increasing soil organic carbon. 4) The addition of OM amendments is a win-win situation as a solution for organic matter waste recycling, and simultaneously to improve soil quality.



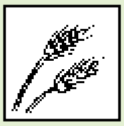
Location: Mato Grosso
Region: Campo Verde
Technology area: 0.011544 km^2
Conservation measure: agronomic
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago); externally / introduced through project, recent (<10 years ago)
Land use type: cropland: Annual cropping
Climate: subhumid, tropics
WOCAT database reference: T_BRA004en
Related approach: none
Compiled by: Luisa F. Vega, Christian-Albrechts University of Kiel, Germany, luisa.vega@gmail.com; Ricardo S. S. Amorim Federal University of Mato Grosso, Brazil, rsamorim@ufmt.br; Stefan Hohnwald, Georg-August-University of Göttingen, Germany shohnwa@gwdg.de
Date: July, 2016

carbiocial
Universidade Federal de Mato Grosso
UNIVERSITÉ FRANÇOIS - RABELAIS TOURS
C A U
Christian-Albrechts-Universität zu Kiel

Classification

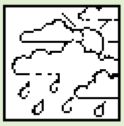
Land use problems: Croplands demonstrate a reduction in soil organic matter, after their conversion from indigenous vegetation into agricultural fields. It is especially critical in the ferrasol soils of the Brazilian Cerrado, as its organic matter content is relatively low, and tropical temperatures and humidity accelerate microbial activity (Price and Sowers 2004) (expert's point of view). There are also problems regarding soil compaction and rainfall regime change (land user's point of view).

Land use



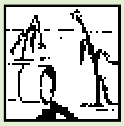
annual cropping: rainfed

Climate



subhumid

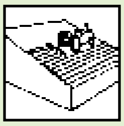
Degradation



chemical soil deterioration: fertility decline and reduced organic matter content

biological degradation: quality and species composition / diversity decline

Conservation measure



agronomic: organic matter / soil fertility; soil surface and subsurface treatment

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative:
Experiments / research: recent (<10 years ago)
Externally introduced: recent (<10 years ago)

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires), soil management, crop management (annual, perennial, tree/shrub).
Indirect causes: population pressure.

Main technical functions:
- increase in organic matter
- increase / maintain water stored in soil

Secondary technical functions:
- improvement of topsoil structure (compaction)
- stabilization of soil (e.g. by soil aggregates)
- increase in nutrient availability (supply, recycling)
- increase of infiltration
- increase of groundwater level / recharge of groundwater
- water harvesting / increase water supply

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 150 days (November to March), 120 days (April to July)
Soil texture: fine / heavy (clay)
Soil fertility: very low
Topsoil organic matter: high (>3%)
Soil drainage/infiltration: good

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: good
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: heavy rainfall events (intensity and amount), wind storms / dust storms.
Sensitive to climatic extremes: temperature increase, floods, droughts / dry spells, decreasing length of growing period.
If sensitive, what modifications were made / are possible: addition of organic matter to the soil can improve water infiltration and holding capacity, increasing soil resilience to floods and droughts.

Human Environment

Cropland per household (ha)

Cropland per household (ha)
<0.5
0.5-1
1-2
2-5
5-15
15-50
50-100
100-500
500-1,000
1,000-10,000
>10,000

Land user: Individual / household, Small-scale land users, average land users, mainly men.
Population density: < 10 persons/km^2
Annual population growth: > 4%
Land ownership: individual, titled
Land use rights: individual
Water use rights: leased (The water use is regulated by the Environmental Secretary of the State (SEMA). Thus, water users have to obtain an Environmental License, whereby the volume of water consumption is declared. The licence is free of charge).
Relative level of wealth: rich, 46% of the land users; average, 51% of the land users; poor, 3% of the land users.

Importance of off-farm income: less than 10% of all income: off-farm income in the Cerrado is usually not significant for farmers. Their income depends principally on agricultural activities such as soybean, maize and cotton.
Access to service and infrastructure: Low: health, education; moderate: market, roads & transport, drinking water and sanitation, financial services; high: technical assistance, employment (e.g. off-farm), energy.
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: no

Technical drawing

Enrichment of tropical agricultural soil (a ferrasol) with organic matter amendments. Experimental design: amendment types, amounts and application methods (direct on the soil or with harrow incorporation). Studied variables: soil carbon and nutrients, soil physical properties (water-holding capacity) and crop yield (soybean biomass and grain production) (Diego Orduz).

Implementation activities, inputs and costs

Establishment activities

Not applicable

Establishment inputs and costs per ha

Maintenance/recurrent activities

1. Transport of amendments by trucks (0.2 tonne/US$)
2. Spreading / incorporation of organic matter by tractor (US$ 3/ha for petrol and US$ 5/ha for tractor driver).

*Five ha can be treated per day

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour (person/ha)	5.00	100%
Equipment		
– tractor use (day)*	15.00	100%
– truck transport (30 tonnes/ha)	150.00	100%
TOTAL	**170.00**	**100%**

Remarks: The used organic matter amendments are cost-free. It is suggested to use cost-free materials if possible or cost–efficient materials to reduce implementation and maintenance costs. Transport of amendments is paid by tonne, independently of the type. The OM application methods (direct on the soil by hand or with harrow incorporation) did not show significant differences. For this reason only the costs for the tractor were calculated, because it is a more economic option.

Assessment

Impacts of the Technology

Production and socio-economic benefits

++ reduced expenses for agricultural inputs
++ provides a better environmental and technical use for agro-industrial residues
+ reduced risk of production failure
+ reduced demand for irrigation water

Production and socio-economic disadvantages

−− costs of transport and application of OM amendments

Socio-cultural benefits

++ improved conservation / erosion knowledge

Socio-cultural disadvantages

Ecological benefits

++ increased soil micro-organisms and fauna

Ecological disadvantages

Off-site benefits

Off-site disadvantages

Contribution to human well-being / livelihoods

Enrichment of Tropical agricultural soil with organic matter amendments is a solution for organic matter waste recycling.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	positive
Maintenance/recurrent	slightly negative	positive

The technology cost of maintenance is the same as establishment cost. According to the results, amendments should be reapplied every two years, starting with amounts as little as 6 t/ha.

Acceptance/adoption: There is no trend towards (growing) spontaneous adoption of the technology. Antonio Huebner, the land owner and user of the Rio Engano Farm is aware of the technological benefits for soil fertility. However, he considers that costs of transporting and applying OM could hinder the technology incorporation from becoming common practice for soil management.

Concluding statements

Strengths and → how to sustain/improve

The addition of industrial organic matter (OM) waste from levels of only 6 tonnes/ha onwards can significantly increase soil organic carbon on a ferrasol in the Brazilian Cerrado. This increase took place regardless of the type of OM waste applied and even when the soil was under no-tillage for more than 20 years → Amendment reapplication should be done in 2 years intervals.

Weaknesses and → how to overcome

The costs of transport and application can hinder the extensive use of soil OM enrichment practices among land users in the Brazilian Cerrado → Subsidies could encourage the technology adoption.

There is no specific machinery for OM spreading / incorporation, which increases human workload → To reduce human labour, it is recommended to design / adapt machinery for this purpose (e.g. of lime or mulch application machinery). However, more tests and improvements of the application methods are desirable.

Materials used as OM amendments could be toxic and pose a risk of soil pollution → It is important that land users are well informed about the risks. Crude forest material such as sawdust from *peroba* and *cedrinho* or roughly processed material such as filter cake of sugarcane used in this study should not have a toxic effect. Regarding the potential allelopathic effect of eucalyptus, its decomposing biomass does not seem to have a significant inhibitory effect on other crops (Chu et al. 2014)

Key reference(s): Chu, C. et al. (2014) Allelopathic effects of Eucalyptus on native and introduced tree species, Forest Ecology and Management, Volume 323: 79-84 • Price PB, Sowers T (2004) Temperature dependence of metabolic rates for microbial growth, maintenance, and survival. Proceedings of the National Academy of Sciences of the United States of America 101:4631-4636 • Tivet F et al. (2013) Aggregate C depletion by plowing and its restoration by diverse biomass-C inputs under no-till in sub-tropical and tropical regions of Brazil. Soil and tillage research, 126 :203-218 • Zech W. et al. (1997) Factors controlling humific G. ation and Mineralization of soil organic matter in the tropics. Geoderma 79 : 117-161.
Contact person(s): Prof. Dr. Ulrich Irmler , Institute for Ecosystem Research, Christian-Albrechts-Universität Kiel, 24118 Kiel, Germany, uirmler@ecology.uni-kiel.de • Prof. Dr. Karl M. Wantzen, CNRS UMR CITERES, University of Tours, 37200 Tours, France, karl.wantzen@univ-tours.fr, www.karlmwantzen.de
Acknowledgments: We would like to thank Dr. Malte Unger for participating in the experimental design and for setting the experiment in field. We express our gratitude to Mr. Antonio Huebner for granting us permission to work in his farm. We also thank Edwaldo Dias Bocuti for kindly assisting us with information about the study area.

left: Discussing results with land users to raise awareness. (Photo: Stefan Hohnwald)
right: Land use system along Route BR 163. (Photo: Stefan Hohnwald)

From storylines to scenarios: raising awareness and decision support

Brazil

Investigating viable carbon-optimized land management strategies, which maintain or improve ecosystem function, under changing climate conditions in the Southern Amazon - using regional scenarios generated from storylines.

One objective of the Carbiocial project, in close cooperation with its Brazilian partner project Carbioma, is to explore how land use change in one of Brazil's most dynamic regions will develop in the next 30 years and how it will be affected by the implementation of land-use planning options and conservation policies. For this purpose a set of scenarios was created. The scenarios portray different plausible development pathways for the region. Each scenario consists of a storyline: a brief narrative of the future. At this level farmers and institutions are involved. An expert panel translated the findings of several stakeholder workshops and extensive stakeholder and expert interviews, conducted in 2012, into qualitative information needed to elaborate these scenarios. Four storylines emerged: (1) "business-as-usual"; (2) sustainable, extensive use of the Amazon; (3) legal intensification; (3) illegal intensification.
It was agreed that the communication between qualitative social science data and quantitative data had to be considered carefully. A blend of the required input factors for the models was agreed as guiding principles for all storylines: these were: population, agrarian production, livestock, agrarian and environmental policies, protected areas, infrastructure, impact of climate change (mitigation/adaptation). In a second step, qualitative data had to be added to the models; to limit bias, all available German experts on Southern Amazonia participated in a day-long (and quite controversial) brainstorming session producing content for the four storylines.
After translating the results into Portuguese the outcome was discussed with representatives of government and NGOs to discuss their plausibility and to modify accordingly. The input of local stakeholders was included on the basis of discussions and qualitative interviews. Generally speaking, the feedback loops with Brazilian stakeholders' happened rather arbitrarily. Participation could have been better if planned more methodically and earlier.
The three hypothetical storylines describe different pathways of future regional development within the two states. Due to the strong linkages of Southern Amazonia to global markets (e.g. exports of soybean and meat) it was necessary to portray this dependency as one important determinant within the scenarios. Also, law enforcement of the existing legal situation was considered: more than 40% of Amazônia comprises protected areas. In order to portray the possibility of progressive environmental and indigenous legislation, a vibrant civil society, and well-institutionalized public prosecutors, a sustainability scenario was designed.
The next step was the quantification of the qualitative information to facilitate a simulation-based scenario analysis. Simulation models will be combined as software packages to support the decision-taking process from local to landscape and regional scale. All research and implementation activities include direct involvement of the stakeholders. Field experiments for improving C storage and ecosystem function will be performed in cooperation with an NGO founded by the farmers of Mato Grosso.
A set of land use maps was generated to depict scenarios from 2010 to 2030. The objective of this modelling and mapping exercise is to support decision-makers to better interpret the scenarios and their implications. These new layers of information will facilitate further model or GIS-based analysis of land use change impacts on the regional carbon balance and the loss of biodiversity, and may act as a test-bed for the development of strategies towards sustainable land management.

Location: Mato Grosso / Pará, Brazil
Approach area: 2,157,000 km^2
Type of approach: project / programme-based
Focus: scenario building from storylines
WOCAT database reference: A_BRA007en
Related technology: none
Compiled by: Jan Goepel, University of Kassel, Germany, goepel@cesr.de
Date: 18th June 2016

Problem, objectives and constraints

Problems:
High loss of vegetative and soil carbon due to agricultural expansion (deforestation), agricultural emissions, biodiversity loss.

Aims / Objectives:
The joint main goals are 1) to perform region-specific analyses in order to improve and apply interdisciplinary sets of models of land use impacts on carbon stocks, water and GHG balances, 2) to develop and optimize land management strategies that minimize carbon losses and GHG emissions, and maximize carbon sequestration, 3) to assess the trade-offs between land management options and socio-economic impacts in terms of GHG reduction, profitability, ecological sustainability, and last but not least, 4) to support the Brazilian partners to implement the optimal techniques in practice, considering the soybean value chain and overall carbon balance.

Constraints addressed

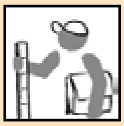
	Constraints	Treatments
Social / cultural / religious	Acceptance of research results	Dissemination of research results in the form of policy briefs (short graphical illustration of results) and "output-stick" (USB stick with more detailed research results).
Legal / land use and / water rights	Land tenure	None

Participation and decision making

Stakeholders / target groups


planners


land users, individual, groups


SLM specialists / agricultural advisors


politicians / decision makers

Approach costs met by:

– International, (German Ministry of Education and Research, BMBF)	100%
Total	**100%**

Annual budget for SLM component: US$ 100,000-1,000,000

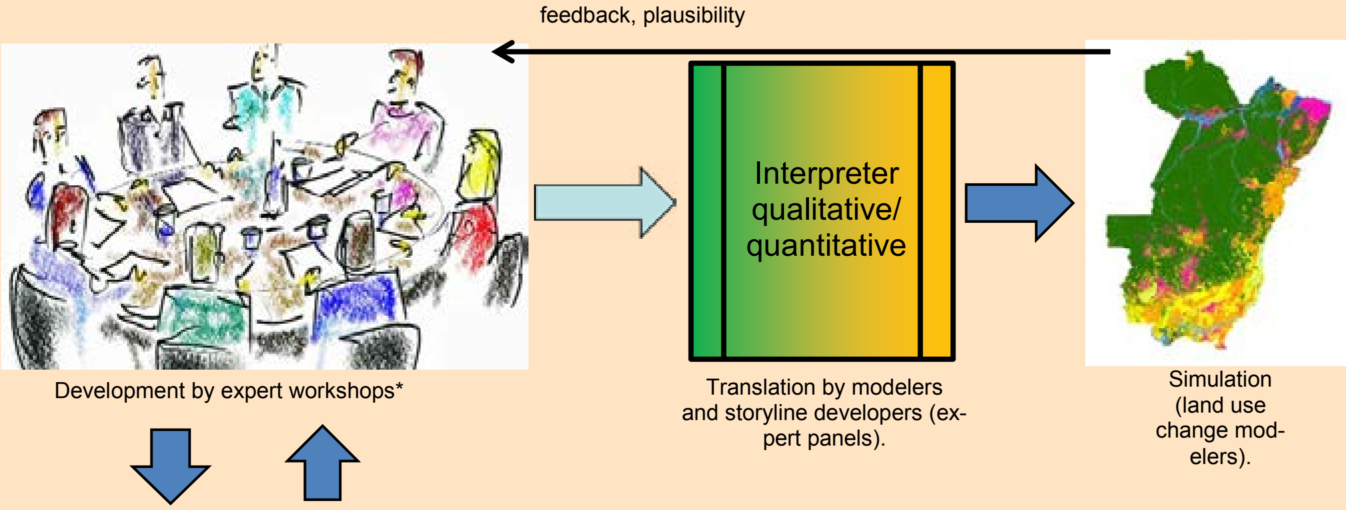
Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users.
Decisions on method of implementing the Technology: By land users alone (own-initiative / bottom-up)
Approach designed by: International specialists, land users.
Implementing bodies: Local community / land users, government (planning authorities).

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	Land users and planning authorities; identification of research priorities, state-of-the-art of agricultural practices, identification of problems.
Planning	None	
Implementation	None	
Monitoring/evaluation	None	
Research	Passive	Research plots for demonstration.

Differences between participation of men and women: No

Involvement of disadvantaged groups: Yes, moderate. Indigenous groups were involved in stakeholder workshops with the aim of discussing different storyline options, and in the following feedback loops discussing the resulting storylines.



Organogram:
The scenario building process. Qualitative scenarios (“storylines”) were developed by an expert panel and successively refined with feedback from regional stakeholders and project partners. In the second step the storylines were interpreted, quantified, and used for scenario building and analysis based on computer models.

*http://www.csee.umbc.edu/wp-content/uploads/2012/11/meeting_cartoon.jpg

Technical support

Training / awareness raising: Training provided for land users. Training comprised demonstration areas, public meetings, site visits / farmer-to-farmer visits. Training focused on raising awareness of the consequences of “business-as-usual” behavior compared with other scenarios.
Advisory service: Name: dissemination of research results in the form of policy briefs and more detailed “output sticks” (see above)
Research: Yes, great research. Topics covered include technology and ecology. Mostly on-farm and on-station research.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Not relevant
Input: See above
Credit: Credit was not available
Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	ad hoc observations by project staff
area treated	ad hoc observations by project staff
no. of land users involved	ad hoc observations by project staff
bio-physical	ad hoc measurements by project staff
socio-cultural	observations and measurements by project staff
economic / production	observations by project staff

Changes as result of monitoring and evaluation: There were few changes in the approach. Dissemination; form of dissemination was adjusted according to the requirements of target groups. There were no changes in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, moderate. Identification of method of applying organic matter to soil; identification of kind of agriculture most suitable for specific region/area; type of crop sown; crop sowing dates; economic return/economic optimization.

Adoption by other land users / projects: Yes, few

Improved livelihoods / human well-being: No

Improved situation of disadvantaged groups: No

Poverty alleviation: No

Training, advisory service and research:

- Training effectiveness:
  Politicians / decision makers and planners: fair
  Land users: good
- Advisory service effectiveness:
  Politicians / decision makers, planners, land users: good
  Research contributing to the approach's effectiveness: Greatly

Land/water use rights: Hindering greatly in the implementation of the approach. Especially in Pará, land tenure rights are uncertain and lead to land speculation with resultant land degradation and deforestation. The approach did not reduce the land/water use rights problem at all. Research had no effect on land tenure; research was not aimed at solving the problem, rather research helped to identify the problem

Long-term impact of subsidies: None

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production. Increased profitability, improve cost-benefit ratio. Payments / subsidies. Rules and regulations (fines) / enforcement. Well-being and livelihoods improvement

Sustainability of activities: Yes, the land users can sustain the approach activities without support. No-till agriculture, crop rotations, recommended sowing dates, expanding agricultural land according to crop yield information, and information regarding negative effects of cropland/rangeland expansion (e.g. soil and site specific GHG emissions) which were identified through the different scenarios.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
improved choice of crop/crop rotation; more environmental friendly choice of kind of agriculture employed (agroforestry systems); improved awareness of existence and functionality of regulations in favor of sustainability better dissemination; heightened awareness of land users to sustainability topics and environmental degradation.	Acceptance of results by famers, planning authorities, decision makers in general (political level).

Key reference(s): J. Goepel et al. (2016) Future scenarios of land-use and land-cover change in Southern Amazonia and resultant greenhouse gas emissions from agricultural soils, to be published in Regional Environmental Change Special Issue "Southern Amazonia",(in review) • Schönenberg et al. (2016) Inter- and transdisciplinary scenario construction to explore future land use options in Southern Amazonia, to be published in Ecology & Society (in review) • R. Schaldach et al. (to be published) A multi-scale modelling framework for the analysis of societal and environmental processes in Southern Amazonian land systems: Lessons learned from the Carbiocial project.

Contact person(s): Juliana Gil, Embrapa Rice & Beans, Brazil, julianagil@uol.com.br

left: The “Green Liver System” after planting the macrophytes and filling the tank with water. (Photo: Érika Marques)
right top: View of section containing the macrophyte *Eichhornia crassipes*.
right bottom: Demarcation and planting of macrophyte *Egeria densa* (Photo: Érika Marques)

The “Green Liver System”: eco-friendly water purification

Brazil - *Fitorremediação* (Portuguese)

Water purification using macrophytes to treat effluent from fish farming.

The Itaparica reservoir was completed in 1988 to generate hydropower. About 40,000 people were compulsorily relocated. The construction of the reservoir lead to a shortage of fish, making aquaculture a viable and profitable alternative. However excess feed and excreta of fish add nutrients and pollute water.

The “Green Liver System” uses aquatic plants, established in artificial wetlands, to remove, transfer, stabilize or eliminate pollutants in wastewater from fish farms. The use of large quantities of feed in aquaculture, along with the application of antibiotics, hormones and probiotics, has negative impacts on aquatic ecosystems due to the introduction of nitrogen, phosphorous and drug residues into the system. The Green Liver System is a form of phytoremediation (phyto = plant and remediate = correct) that uses a range of plants to decompose, extract, or hold contaminants present in soils and waters. This technology has been considered as an innovative alternative and a low cost option compared to others used in contaminated sites - like membrane bioreactors, upflow anaerobic sludge blanket (UASB), and others.

The plants selected for use in Green Liver System artificial wetlands depend on the pollutant to be removed. Research shows physiological differences between species, which need to be taken into account when planning wastewater treatments. Ideal plants for phytoremediation need: a) a fast growth rate; b) high biomass production; c) long rooting systems; d) easy maintenance/pruning; e) to be able to persists, and f) to have the ability to store trace metals within specific parts which can be later removed.

The Green Liver System uses aquatic macrophytes, which extract contaminants from the water, store them, or even metabolize them - transforming them into less toxic or harmless products. In the case of *Eichhornia crassipes*, most of the solids in suspension are removed by sedimentation or by adsorption in the root system. The dense coverage of these plants reduces the mixing effect of the wind, as well as minimizing thermal mixture. Shading by the plants restricts algal growth and the root system prevents horizontal movement of particulate material. In this way, particles are removed from the wastewater and microorganisms associated with the plants' rhizosphere slowly decompose. Many organisms can be used in biodegradation: these include bacteria and fungi as well as plants, and the efficiency of one or the other depend, in many cases, on the molecule structure and of the presence of enzymes that are effective in degrading the pollutant.

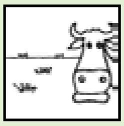
The fish farm used as an example here is located on the margins of the Itaparica reservoir in Brazil. There are dozens of excavated tanks used to produce tilapia (*Oreochromis niloticus*) and “tambaqui” (*Colossoma macropomum*) fingerlings and juvenile fish. As well as these tanks, there are many net enclosures installed in the reservoir where the fishes are reared to maturity. Part of the wastewater from the excavated tanks is released into a stabilization lagoon, and the remainder goes to the Green Liver System. The effluent is enriched with spare feed, and excreta from the fish, which includes drug residues. If not treated, this may cause eutrophication because of its mineral richness. The Green Liver System consists of an excavated tank of 100m x 20m x 2m in size. The tank is subdivided into six parts: two planted to *Eichhornia crassipes* and four to *Egeria densa*. A mesh barrier stops fish from being flushed into the tank. Regular monitoring of the physical, chemical and biological parameters is required to control environmental fluctuations.

Location: Pernambuco
Region: Vila do Coité, Itacuruba
Technology area: 2 km^2
Conservation measure: vegetative
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago**)**
Land use type: reservoir, ponds, dams; extensive grazing land (before)
Climate: semi-arid, tropics
WOCAT database reference: T_BRA007en
Related approach: none
Compiled by: Érika Alves Tavares Marques, Universidade Federal de Pernambuco; Rua Professor Júlio Ferreira de Melo, n° 756 /apt° 201, Boa Viagem, Recife, PE, Brasil, CEP 51.020-231. erikatmbio@gmail.com
Date: 17 January 2014, updated June 2016

Classification

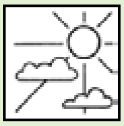
Land use problems: The agricultural economy of this semi-arid region is characterized by pastoral activities, as well as the cultivation of crop species resistant to drought, such as cotton, corn (maize), beans, and cassava. Irrigation from the reservoir was potentially possible but investments in aquaculture proved more profitable. In general, the commercial companies involved do not treat effluent, leading to pollution. Even though monitoring is mandatory, almost nobody does it, nor do they make substantial efforts to purify the effluent (expert's point of view).
There are several conflicts over water and related land use in the region. Some people say the water quality in the reservoir is good (and use it directly for drinking), others report ill-health especially during times of low water levels. Commercial aquaculture primarily produces tilapia. The hydroelectric company manages the reservoir according to national needs in electricity – thus sudden water level fluctuations are frequent. Commercial aquaculture and associated land use dominate the shoreline, preventing access for artisanal fishermen to their traditional fishing grounds (land user's point of view).

Land use



Extensive grazing land (before);
Reservoir, ponds, dams

Climate

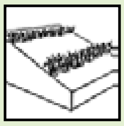


semi-arid

Degradation

water degradation:
decline of surface water quality

Conservation measure



vegetative:
macrophytes,
different species

Stage of intervention

- □ Prevention
- ■ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative
- ■ Experiments / research: recent (<10 years ago)
- □ Externally introduced

Level of technical knowledge

- ■ Agricultural advisor
- ■ Land user

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires), over-exploitation of vegetation for domestic use, overgrazing, urbanization and infrastructure development, discharge (point contamination of water), over-abstraction / excessive withdrawal of water (for irrigation, industry, etc.)
Direct causes - Natural: change in temperature, change of seasonal rainfall, droughts
Indirect causes: poverty / wealth, inputs and infrastructure, education, access to knowledge and support services, war and conflicts, governance / institutional

Main technical functions:
- improvement of water quality, buffering / filtering water

Secondary technical functions:
- nutrient control, ornamental function

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- ▒ 500-750
- ■ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- ▒ 500-1000
- ■ 100-500
- □ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- □ flat
- □ gentle
- □ moderate
- ■ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- □ 0-20
- ■ 20-50
- □ 50-80
- □ 80-120
- □ >120

Growing season(s): all year due to tropical climate
Soil texture: medium (loam)
Soil fertility: low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: poor (e.g. sealing /crusting)

Soil water storage capacity: very low
Ground water table: < 5 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic gradual change and extremes: In tropical areas, macrophytes grow all year. Ideal temperature range for *E. crassipes* (water hyacinth) development is between 25 and 31°C. The water hyacinth is a very fast growing plant, with populations known to double in as little as 12 days.
Sensitive to climatic gradual change and extremes*:* *E. crassipes* (water hyacinth) can tolerate extremes of water level fluctuation and seasonal variations in flow velocity, and extremes of nutrient availability, pH, temperature and toxic substances. *E. densa* is a very resistant plant and grows very fast, but the plant does not tolerate temperatures above 30°C.

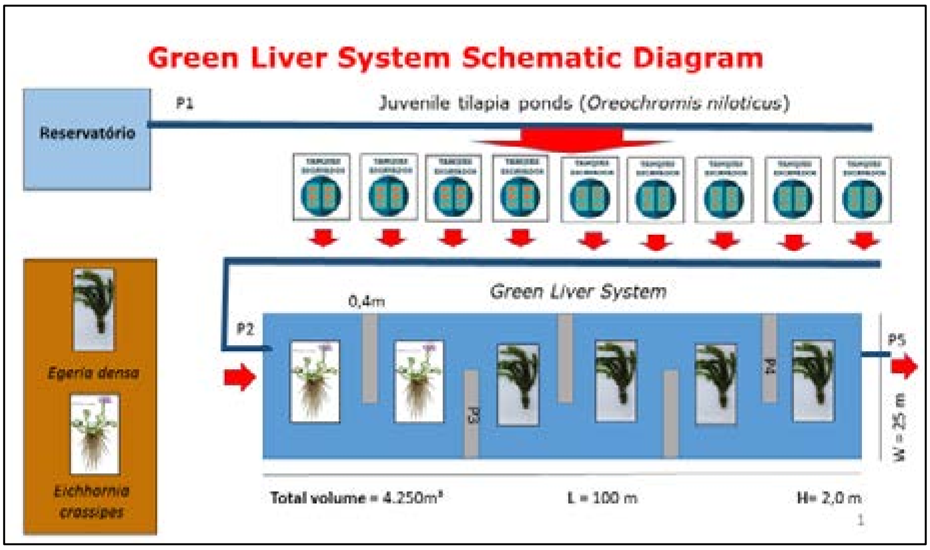
Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
☐	5-15
☐	15-50
■	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: Individual / household, small-scale land users, average land users, mainly men
Population density: < 10 persons/km^2
Annual population growth: 1% - 2%
Land ownership: State
Land use rights: Individual
Water use rights: Needs official registration and permission; heavy water use has a price
Relative level of wealth: Average

Importance of off-farm income: > 50% of all income
Access to service and infrastructure: Low: health, technical assistance, employment (e.g. off-farm), drinking water and sanitation, financial services, extension service; moderate: education, market, roads & transport; high: energy
Market orientation: mixed (subsistence and commercial)
Mechanization: none
Types of other land: Sporadically used by free-grazing livestock (mainly goats)



Technical drawing

The constructed wetland termed a “Green Liver System” is 100m x 25m x 2.0m in size. It is divided into six parts (one third of the tank planted with *Eichhornia crassipes* the remainder with *Egeria densa*). The average outflow during the period was 1,800 m³/h. Point P1 is the catchment from the reservoir. Point P2 is the inlet that receives the discharge of effluent from 10 ponds with juvenile tilapia (*Oreochromis niloticus*). Point P3 is the stage after the treatment with *Eichhornia crassipes*. Point P4 is the stage of the treatment with *Egeria densa*. Point P5 is the outlet into a containment basin. (Stephan Pflugmacher-Lima)

Implementation activities, inputs and costs

Establishment activities

1. Digging the pit (truck), stabilizing the walls
2. Building separation walls (construction costs: USD 3000 / unit
3. Fencing (cutting fence posts: USD 160 / unit)
4. Planting macrophytes in place (costs: USD 1900 / unit)

Establishment inputs and costs per unit

Inputs	Costs (US$)	% met by land user
Labour	5060.00	0 %
Supervision	1000.00	0 %
Equipment:		
– truck	125.00	0 %
Construction material		
– walls/baffles (cement)	475.00	0 %
– barbed wire	315.00	0 %
– earthwork	250.00	0 %
– tubular elements	30.00	0 %
TOTAL	**7255.00**	**0 %**

Maintenance/recurrent activities

1. Exchange macrophytes

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	3000.00	0 %
Equipment:		
– nylon fabric	38.41	0 %
TOTAL	**3015.00**	**0 %**

Remarks: Because of the tropical climate in the northeast of Brazil there is a need to remove *Eichhornia crassipes* periodically because it grows very fast (plenty of nutrients and warm temperatures all year). The cost of removal of the macrophytes is permanent and must be made monthly as the plant reaches adulthood it loses its capability of removing nutrients and gives it back to the water.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ increased drinking water availability ++ increased water availability / quality ++ increased irrigation water availability quality	−− increase of maintenance costs as manual labour is required for management of macrophytes.
Socio-cultural benefits	**Socio-cultural disadvantages**
Ecological benefits	**Ecological disadvantages**
++ increased water quality	−− nylon mesh (prevent the macrophytes from occasionally breaking loose into the reservoir).
Off-site benefits	**Off-site disadvantages**

Contribution to human well-being/livelihoods and support to decrease eutrophication in reservoir and channels.

\+ the technology contributed to improved water quality, which is directly related to people's health.

Benefits/costs according to land user

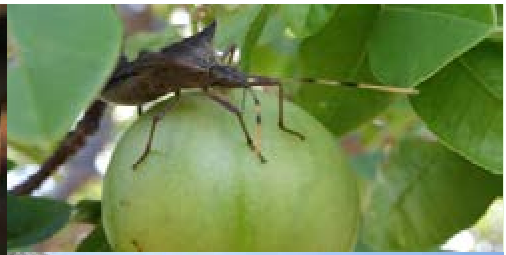
Benefits compared with costs	short-term:	long-term:
Establishment	positive	positive
Maintenance/recurrent	positive	positive

Acceptance/adoption: There is little trend towards (growing) spontaneous adoption of the technology. Broad adoption is not yet expected at this stage of experimental analysis and testing. However a few people have already expressed interest.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Water purification is achieved by using natural processes → If the related tilapia fish production unit could be awarded a "green" or "ecological" brand, this would be beneficial and maybe trigger the adoption of the technology.	From time to time the macrophytes have to be removed, tubes may need cleaning and the system needs to be set up again. Sometimes, the removal of almost all water may be indicated. Major maintenance can cause peak labour needs. Manual labour required to monitor the system on a regular basis, and perform maintenance according to needs. Depending on the number and size of Green Liver Systems in action, caring for them can be a full-time job → The maintenance costs have to be well budgeted in the overall planning of costs and benefits of the related productive units.
Among the advantages of adopting the Green Liver System are the low costs, the speed of construction and its relatively easy operation → Easily accessible and comprehensive information is needed, as well as the possibility of exchanging experience among users or future users.	Additional manual labour increases costs (and hinders adoption) → The more people use such techniques, for instance due to improved environmental monitoring and fines imposed, the more such extra expenditure will be accepted as regular running costs .
If the environmental authority increases controls of how effluent from aquaculture ponds is handled (checking pollution and nutrient loads in the effluent which is usually returned to the reservoir without any treatment), the technology would help compliance with existing rules → Enhancing control and penalties would favour the adoption of such a green technology. Currently controls are rare or non-existent.	The disposal of the removed macrophytes is still a problem to be solved. If the macrophytes have accumulated high levels of toxins, the biomass cannot be used for compost making or livestock feeding → The removed macrophytes should be analysed for their pollutant content. A biodigester could be the solution to the disposal of contaminated biomass, generating energy for the productive unit and possibly for the local population too.
The technology can be constructed using locally available material. → As long as cheap labour is available and rural shops exist, the availability of inputs is adequate.	The management of the system is not simple. Many different and unexpected disturbances can occur. Experience and close, constant watch out is needed → Exchange of experience among users would facilitate its management. An updated list of threats could be helpful.

Key reference(s): Pflugmacher, S. et al. (2015) Green Liver Systems® for water purification: Using the phytoremediation potential of aquatic macrophytes for the removal of different cyanobacterial toxins from water. AJPS 06 (09), 1607–1618. doi:10.4236/ajps.2015.69161.• Nimptsch, J.et al. (2008) Cyanobacterial toxin elimination via bioaccumulation of MC-LR in aquatic macrophytes: An application of the "Green Liver Concept". Environ. Sci. Technol. 42 (22), 8552-8557. doi:10.1021/es8010404
Contact person: Érika Alves Tavares Marques, Universidade Federal de Pernambuco; Rua Professor Júlio Ferreira de Melo, n° 756 /apt° 201, Boa Viagem, Recife, PE, Brasil, CEP 51.020-231. erikatmbio@gmail.com • Stefan Pflugmacher Lima, Technische Universität Berlin, Institute of Ecology, Faculty VI, Ernst-Reuter-Platz 1, 10623 Berlin, Germany, stephan.pflugmacher@tu-berlin.de.



left: *Hypsiboas raniceps* frog in a plantation of guava. (Photo: Maike Guschal)
right top: Bug feeding on local *umbu* (*Spondias tuberosa)* fruit. (Photo: Maike Guschal)
right below: Typical tree plantation (coconut) of the region (Photo: Maike Guschal)

Biological pest control through promoting habitats for native fauna

Brazil - *Controle biológico de pragas pela fauna nativa: manter ou restabelecer habitats respectivos*

Reducing the use of common agrochemicals by supporting preferred habitats of biological pest control agents like amphibians and by using alternative self-made organic pesticides.

Irrigated crops attract various pest species. Farmers usually address crop pest and disease problems through the use of agrochemicals. Especially bees, birds, and amphibians, which fulfil important functions in agroecosystems, are affected by high use of agrochemicals. The combination of inappropriate irrigation practices, incorrect application rates of agrochemicals, and low producer prices often lead, however, to poor income from smallholder irrigated agriculture and to further problems such as poor health, loss of biodiversity, and soil and water contamination. Amphibians are themselves proven biological pest control agents of arthropod pest species (predators of e.g. larvae of butterflies, beetles, termites, bugs and others) and the incorrect use of agrochemicals, as well as the removal of vegetation along field margins hampers this useful function. The technology described here aims to support and utilise the potential of amphibians (such as frogs and toads) as biocontrol agents –as an alternative to agrochemicals in crops.

Establishing habitats for amphibians is crucial in order to increase and secure their numbers: for example encouraging shrubby vegetation next to water bodies for arboreal frogs, and installing additional water ponds inside and around plantations for ground-living frogs. First, the local species pool of amphibians needs to be determined by visual and acoustic observations. Amphibian species do not need to be determined precisely, but it is important to detect whether they are arboreal and/or ground-living amphibians, as these two groups have different roles as biocontrol agents. Pests that feed on the main cultivated species should be characterized by (a) collecting plant material to determine the type and quantity of pests and (b) by comparing observations with neighbouring farmers and extension agents. Pest species can be determined also by installing traps and using nets. Inspection should be done at least every 15 days to once a month during the whole rainy season to detect possible mass reproduction of arthropods after rainfall events. Once amphibians and pest species are detected, decisions on management strategies can be made. Such a strategy is to create habitats for amphibians with additional sources of income, e.g. by planting pomegranate or guavas as shrubby vegetation structure for arboreal frogs. If pest species can't be reduced solely by amphibian species, the use of agrochemicals has to be reconsidered. Preference shall be given to chemicals which do not harm amphibians. Organic, self-made pesticides based on the extract of manioc roots (*manipoera*) seem promising. Twenty litres of *manipoera*, the bark of manicoba tree (*Manihot pseudoglaziovii*), a cup of American wormseed (*Dysphania ambrosioides*), a cup of yellow tagetes (*Tagetes sp.*), a cup of malagueta pepper (*Capsicum sp.*), garlic and a little bit of bleach have to be chopped, mixed and fermented for 10 days. Application of the final product (25 ml of organic pesticide diluted in 20 l of water) should be done every 8 to 15 days depending on crop species.

Increasing habitat heterogeneity stimulates the diversity of amphibians and so a greater number of pest types will be controlled. Combined control by safeguarding natural amphibian habitats and application of organic pesticides is an innovative alternative to the overuse of toxic agrochemicals.

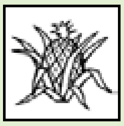
Location: Floresta, Itacuruba, Petrolandia
Region: Brazil, Pernambuco
Technology area: 0.1 - 1 km^2
Conservation measure: vegetative, structural, agronomic
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: developed through experiments / research, traditional (>50 years ago)
Land use type: cropland: perennial and annual cropping; grazing land: Intensive grazing/ fodder production
Climate: semi-arid, tropics
WOCAT database reference: T_BRA010en
Related approach: none
Compiled by: Maike Guschal, Museum of Zoology, Senckenberg Natural History Collections Dresden, 01109 Dresden, Germany, e-mail: maike.guschal@gmail.com
Date: 1st January 2015, updated June 2016

INNOVATE

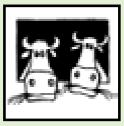
Classification

Land use problems: Intensive livestock grazing pressure, agriculture and logging of native vegetation are the driving factors behind loss of the Caatinga dry forest. The high use of agrochemicals additionally pollutes soils and watersheds, and probably also decreases local biodiversity. Droughts seem to occur more frequently and these decrease water and food availability for livestock, as well as affecting the local fauna (expert's point of view). Droughts and consequently problems of feeding livestock on natural vegetation (lack of fodder and grazing grounds), deforestation, extensive and inappropriate use of agrochemicals, low producer prices (land user's point of view).

Land use

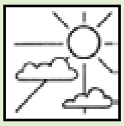


perennial (non-woody) &annual cropping; , tree and shrub cropping;



intensive grazing / fodder production, mainly irrigated

Climate



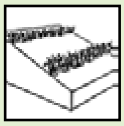
semi-arid

Degradation

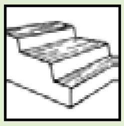
biological: loss of habitats; diversity decline; loss of predators; increase of pests/diseases

water: change in quantity of surface water

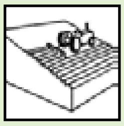
Conservation measure



vegetative: grasses and perennial herbaceous plants; tree and shrub cover



structural: water ponds



agronomic: vegetation / soil cover, organic chemicals for pest control

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative: traditional (>50 years ago)
Experiments / research: traditional (>50 years ago)
Externally introduced: recent (<10 years ago)

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: crop management (annual, perennial, tree/shrub), deforestation / removal of natural vegetation (incl. forest fires), overgrazing.
Direct causes - Natural: change in temperature, change of seasonal rainfall, Heavy / extreme rainfall (intensity/amounts), droughts.

Main technical functions:
- improvement of ground cover
- increase of biomass (quantity)
- improve habitat and habitat diversity
- promotion of vegetation species and varieties

Secondary technical functions:
- increase / maintain water stored in soil
- increase in nutrient availability (supply, recycling,…)
- increase of surface roughness
- stabilization of soil (e.g. by tree roots against landslides)
- increase in organic matter

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

Not relevant

Growing season(s): permanent water source: the whole year; temporary water source: January to May
Soil texture: coarse / light (sandy)
Soil fertility: low, very low
Topsoil organic matter: medium (1-3%), low (<1%)
Soil drainage/infiltration: medium, poor (e.g. sealing/crusting)

Soil water storage capacity: low, very low
Ground water table: around 50 to 80 m deep
Availability of surface water: poor/none
Water quality: poor drinking water
Biodiversity: medium, low

Tolerant of climatic gradual change and extremes: temperature increase, seasonal rainfall increase, wind storms / dust storms, floods, decreasing length of growing period
Sensitive to climatic gradual change and extremes: seasonal rainfall decrease, heavy rainfall events (intensities and amount), droughts / dry spells. Abundance of amphibians is likely to increase with higher rainfall quantity and intensity, this probably results in better pest control. In case of frequent droughts, reptiles like lizards become more important as they do not depend so much on rainfall.

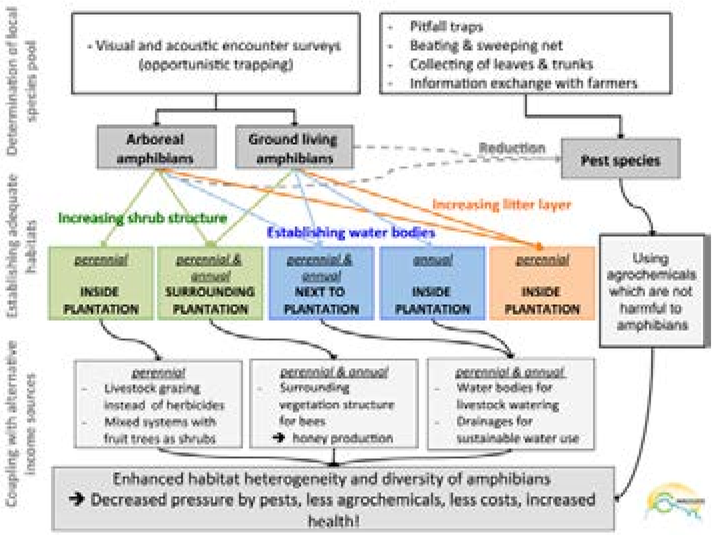
Human Environment

Cropland per household (ha)

	<0.5
	0.5-1
	1-2
	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual / household, medium scale land users, average land users, men and women
Population density: 10-50 persons/km^2
(All types of Land ownership and land use rights can be found in the study region)
Annual population growth: 1% - 2 %
Land ownership: State
Land use rights: Individual
Water use rights: Needs official registration and permission; heavy water use has a price
Relative level of wealth: Average

Importance of off-farm income: 10-50% of all income: the same, there are just single farmers who use the technology currently.
Access to service and infrastructure: Low: technical assistance, employment (off-farm), drinking water and sanitation, financial services; moderate: health, education, market, energy, roads & transport.
Market orientation: subsistence (self-supply), mixed (subsistence and commercial)
Mechanization: low to no
Livestock grazing on cropland: low, should be more focused in future



Technical drawing

Vegetation structures surrounding plantations beside waterbodies guarantee the occurrence of arboreal and ground-living amphibians. Arboreal frogs prefer shrubby vegetation. Since mowing or application of herbicides often eliminates shrubs, moderate livestock grazing might be a better option. The additional water bodies outside the plantation can thereby be used for livestock watering, as long as the surrounding vegetation structure is not eliminated through grazing. Fruit trees such as Guava or Pomegranate as shrub structure provide an additional source of income. To ensure the presence of ground-living frogs, smaller water bodies must be promoted within the plantation. Here puddles from leaky irrigation systems seem to be sufficient already.
Only agrochemicals and organic pesticides that are harmless to amphibians should be used as additional chemical pest control.(M. Guschal & L. Steinmetz)

Implementation activities, inputs and costs

Establishment activities

Establishing habitats for the pest-controlling amphibians
1. Installing of additional small and large water bodies:
   a. large ponds outside the plantation (~100 m²/pond, ~ 4 ponds/plantation, one working day per pond)
   b. smaller ponds for ground-living frogs inside the plantation (one working day/ 5 ha).
   c. drainages can be installed instead of ponds outside the plantation for sustainable water use (machine rent)
2. Planting shrubby vegetation or fruit trees outside and inside the plantation. Planting of Guava trees as shrubby vegetation: 25% density compared to Guava monoculture (e.g. 1.25 working days for exclusive Guava plantation)
3. As irrigation was free in the study region, there were no costs calculated.
4. Knapsack sprayer for application of pesticides

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour		
– constructing of large ponds	~ 36.00	
– constructing small ponds	~ 01.80	
– planting 100 Guava trees/ha	~ 11.25	
Equipment		
– rent of machine for pond or drainage ditch excavation	~ 100.00	
– knapsack sprayer	~ 90.00	
Agriculture		
– fruit tree seedlings (100)	~ 75.00	
TOTAL	**~ 314.05**	**100 %**

Maintenance/recurrent activities

1. Monitoring amphibian species at least 3 nights in the rainy season (can be done by the farmer himself)
2. Monitoring of pest species (1 hour/ha) at least every 15 days in the rainy season (5 month/year) and once a month in dry season (7 month/year) (can be done by the farmer himself)
3. Production and application of organic pesticides (25 ml of organic pesticide diluted in 20 l of water and applied every 8 to 15 days). Note: for commercial pesticides the application costs are the same.
4. Application of fertilizer (1 working day/ year)
5. Pruning of trees (5.25 working days(/year)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour		
– monitoring of frogs	~ 27.00	
– monitoring of pest species	~ 18.00	
– production and application of organic pesticide	~720.50	
– pruning	47.25	
– fertilizer application	~ 9.00	
TOTAL	**~ 821.75**	**100%**

Remarks: To calculate the above example a scenario with maximum activities was taken. Any other scenario will be cheaper. Prices are from the year 2013. Real 1 = USD 0.3.. A total of 6 liters of concentrated organic pesticides per hectare per year are needed. This applies for both self-made and commercial pesticides. As commercial organic pesticides cost about USD 36 per liter, farmers spend USD 216 less per year for self-produced organic pesticides. Similarly commercial non-organic pesticides are more expensive compared to self-made organic pesticides. An additional income of USD 120 / ha / harvest were estimated for guava trees even under possible poor conditions like shadow and extensive management. Other additional sources of income are from the sale of self-produced organic pesticides and livestock grazing instead of using herbicides.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- ++ reduced expenses on agricultural inputs
- ++ diversification of income sources
- + increased crop yield
- + increased fodder production

Production and socio-economic disadvantages

- − reduced livestock production (high number of livestock will decrease favourable vegetation structure for predators)
- − loss of land

Socio-cultural benefits

- + reduced pesticide toxic effect on human health

Socio-cultural disadvantages

Ecological benefits

- +++ increased animal diversity
- +++ increased plant diversity
- +++ increased biological pest / disease control
- +++ increased / maintained habitat diversity

Ecological disadvantages

- − increased niches for pests

Off-site benefits

- +++ reduced downstream flooding

Off-site disadvantages

Contribution to human well-being/livelihoods

- +++ less use of agrochemicals

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	slightly negative	positive

Acceptance/adoption:
Technology is still in the testing phase and it is too early to give any data on acceptance or adoption.

Concluding statements

Strengths and → how to sustain/improve

A strong advantage is the low cost of this ecosystem service which is provided almost freely to farmers, especially when the potential for pest control (abundancy of useful amphibians) is high enough to eliminate the need for agrochemicals → Establish adequate habitats to maintain high diversity of the relevant reptiles and amphibians.

Less use of agrochemicals results in a healthier environment for producers and consumers → If the potential of the reptiles and amphibians is not high enough to combat all pest species, organic chemicals or alternative biocontrol species could be used (for example horntails etc.).

Changing monoculture to mixed systems - or even agropastoral systems - offers additional income sources, while diversification often as a buffer to sudden drops in the price of a particular crop → The crop mixture needs to be well designed, to ensure that the harvests of important crops are not affected too much, and the reduction compensated for by the others.

Weaknesses and → how to overcome

Droughts and limited water availability influence species richness of amphibians → Providing sufficient water bodies for amphibians to overcome prolonged droughts is recommended.

Key reference(s): Guschal & Hagel et al. Benefits of site-adapted management (pest-control) innovations in northeastern Brazil. In preparation.
Contact person: Dipl. Biol. Maike Guschal, Museum of Zoology, Senckenberg Natural History Collections Dresden, Königsbrücker Landstr. 159, D-01109 Dresden, Germany, e-mail: maike.guschal@gmail.com • Dr. habil. Raffael Ernst, Curator Herpetology, Museum of Zoology, Senckenberg Natural History Collections Dresden, Königsbrücker Landstr. 159, D-01109 Dresden, Germany, email: raffael.ernst@senckenberg.de • Dr. Heinrich Hagel, Food Security Center, University of Hohenheim,, Wollgrasweg 43, D-70599 Stuttgart, Germany, e-mail: heinrich.hagel@uni-hohenheim.de

left: Group in a constellation analysis workshop. (Photo: Liron Steinmetz)
right top: Workshop group arranging elements. (Photo: Liron Steinmetz)
right below: Flowchart showing assembled constellation analysis. (Photo: Liron Steinmetz)

Constellation Analysis

Brazil, Análise de Constelação

Constellation Analysis is a tool used to clarify perceptions of different stakeholders about critical situations or problems. In workshops, participants visualize interrelationships between actors, as well as the associated natural, technical and regulatory factors.

The Constellation Analysis method (CA) aims at a transparent, mutually accepted visualization of factors ('elements') that are systematically arranged under the method's four categories: actors; rules and concepts; natural elements; technical elements, with the type of their inter-relationships. The process enables consensus to be found between divergent positions, paving the way for better informed decision-making while facilitating a negotiated process of land management with potential changes/techniques.

During brainstorming and/or literature-based approach, different elements are determined and arranged visually on a board. Element categories are actors (e.g. farmers, energy supply company), rules and concepts (e.g. legal framework, plans and programs, regulations), natural factors (e.g. climate, vegetation, water) and technical factors (e.g. fertilizer, wastewater treatment, hydropower plant). Usually this is done by using differently coloured and shaped cards to help articulate ideas within a working group. Then, connections among and between the elements are discussed and the form of these interrelations are visualized as being (a) directed, (b) conflictive, (c) non-existent, (d) contradictory, (e) reluctant or (f) interactive. Through this approach the way towards developing solutions (or follow-up CAs) is guided.

The approach was applied at different scales and with different stakeholders with divergent professional expertise and educational levels, e.g. farmers, fishermen, employees of the government, representatives of indigenous tribes, associations, trade unions, and researchers. People found the methodology promising as it raises awareness and organizes information. Training in the methodology has been carried out amongst interested people at two universities, but not yet local development agents.

The visualization is carried out through an iterative group process. A moderator is needed to initiate the process by inviting the different stakeholders to a conducive location, and to facilitate the process. Exchange among participants is enhanced, and this leads to better understanding of different viewpoints in situations of tension or in the understanding of what has evolved through specific developments in the past. During a second analytical step, the main lessons of the visualization are extracted and documented. Here, missing factors/relationships, and consequently the need for action, are detected. For example, insufficient communication between actors could be uncovered, or it may be detected that planning programs need to be improved.

Location: Pernambuco, Brazil, Itaparica Reservoir, Petrolândia
Approach area: > 10,000 km^2
Type of approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: A_BRA003en
Related technology: none
Compiled by: Verena Rodorff, Berlin Institute of Technology, Environmental Assessment and Planning Research Group, 10623 Berlin, Germany; verena.rodorff@tu-berlin.de
Date: April/May 2013, updated June 2016

Problem, objectives and constraints

Problems:

The main problems addressed by Constellation Analysis were governance challenges and conflicts related to land and water resources. Land: soil fertility, soil erosion, biodiversity, land tenure, access to land and water. Water: scarcity, quality, allocation, fish species.

Aims / Objectives:

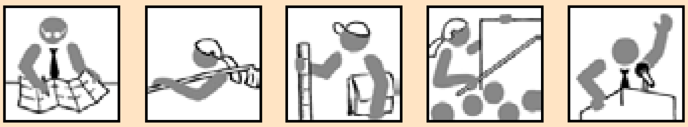
The approach can be applied at different levels and for different issues or contexts: all perspectives can be represented and discussed. The application in this case was devised to be an iterative process of consecutive workshops first at the local irrigation project level, and then at the municipal, regional and national levels with the aim of analysing the inhibiting and driving forces behind the current situation in water management, in land management, and around production cycles in agriculture and aquaculture leading to action being taken or decisions made. Farmers and fishermen, employees of government, researchers and experts are considered as the relevant target group to be involved in participatory workshops. In the education sector, the approach can be applied for theses, for field work and for projects as an analytical interdisciplinary approach.

Constraints addressed

	Constraints	Treatments
Technical	Access to the location can be difficult.	It may be possible to organize a pick-up service for participants or to choose an easy-access location.
Workload	Workload can be high. Workshops often take a whole day.	It is important to discuss potential dates in advance. Some people prefer weekends, others don't. The lunch break is useful for more informal interaction. However others use the break to disappear.
Social / cultural / religious	Participants of disadvantaged social groups are sometimes shy in speaking up in a mixed group. Participants of more advantaged groups occasionally show less commitment than others and are more regularly distracted by their mobile phones.	In some cases, segregation of social or gender groups, especially at the beginning of the exercise, can be helpful. No means has yet been found to reduce 'mobile phone distraction' in an acceptable way.
Other	Constraints can occur due to specific group composition during a CA workshop and the participants' individual backgrounds.	The iterative process of the CA promotes a re-assessment of constellations during different group discussions. Views of dominant individuals can be modified in the iterative procedure, especially when participants with different standpoints and positions are involved. The goal is the mutual understanding of divergent positions towards entry points for change or adaptation.
Institutional	Some institutions might not be happy to send their staff to meetings during working hours.	Argumentation promoting the value of the process may help to 'sell' the approach.

Participation and decision making

Stakeholders / target groups



planners | land users, individual, groups | SLM specialists / agricultural advisors | teachers / school children / students | politicians / decision makers

Approach costs met by:

– international (German Federal Ministry of Education and Research (BMBF)) 100%

Total 100%

Annual budget for SLM component: US$ < 2,000. Project money covered all of the relatively low expenses, hypothetically the approach can be undertaken almost free of costs.

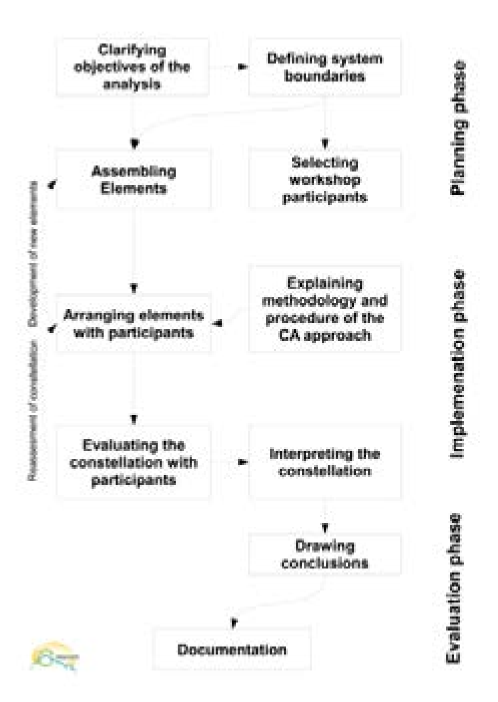
Decisions on choice of the Technology: mainly by land users supported by SLM specialists.
Decisions on method of implementing the Technology: mainly by land users supported by SLM specialists.
Approach designed by: international specialists, national specialists.
Implementing bodies: other (a flexible method to be applied by any group, preferentially mixed stakeholder groups)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Passive	Interviews
Planning	None	None
Implementation	Interactive	Workshops
Monitoring/evaluation	Interactive	Workshops
Research	Interactive	Data analysis, lessons learnt, etc.

Differences between participation of men and women: Yes, little. Smallholder workshop consisted predominantly of male farmers and female fishers as fishery in the study area is traditionally controlled by women.

Involvement of disadvantaged groups: Yes, great. Representatives of a smallholder community, of landless people movement and indigenous communities.



Organogram:
Simplified flowchart of the Constellation Analysis Approach
Planning phase:
Clarify the objective or question behind the analysis. Then, have an overview research about first elements (assembling elements), e.g. which actors can give interesting input and how to contact them. Preparing material for the workshop(s): coloured cards, pens, whiteboard, etc.
Implementation phase:
Explain the objective and methodology to participants, the meaning of the elements: actors; rules and concepts; natural elements; technical elements and their different relations. Clarify rules of respecting each other. Arrange the elements. Evaluate the constellation together with participants, e.g. why are elements far or close to each other? Why are relations conflictive and how to overcome? Are elements or relations missing? Is all information available? What are the next steps? Can recommendations be formulated?
Evaluation phase:
Were participants objective enough? How to interpret participant's activity within the workshop? Which actors should be asked as well? Consolidate participants' statements with literature and research and document. Documentation could be a photo or digitalized picture of results with an explanation based on literature.
(Liron Steinmetz)

Technical support

Training / awareness raising: Training provided for land users, field staff/ agricultural advisors. Training was through workshops. Training focused on detecting knowledge gaps and clarifying positions of players, and the role of natural, technical and regulatory factors from multi-angled viewpoints/perspectives as the core of the CA approach.
Advisory service: The extension system is quite adequate to ensure continuation of activities. Given their willingness, the CA approach is reproducible by stakeholders on their own.
Research: Yes, great research. Topics covered include sociology, technology, economics / marketing, ecology
Mostly on station and on-farm research.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Voluntary
Input: None
Credit: Credit was not available
Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
area treated	Ad hoc observations by project staff, government: joint agreement on the scale of constellation analysis in accordance with stakeholders.
socio-cultural	Regular observations by project staff: attitude, gender, status of workshop participants / stakeholders
management of approach	Regular observations by project staff: feedback on approach by stakeholders: self-evaluation
economic / production	Indicators of profitability, revenue from each stage per person, economic valuation of soil improvement
no. of land users involved	Regular measurements by land users: number of participants in workshops.

Changes as result of monitoring and evaluation: There were few changes in the approach. The moderator needs an assistant; the group size was reduced.

Impacts of the Approach

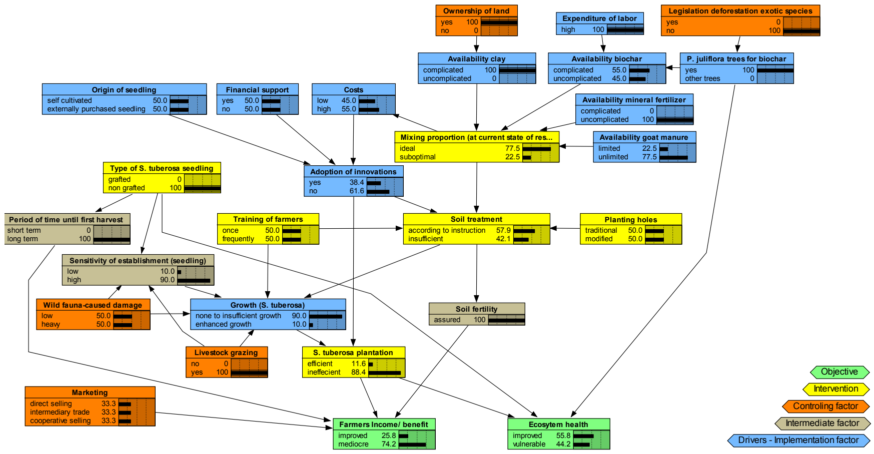
Improved sustainable land management: Yes, little. No immediate impact, however the CA approach could potentially contribute to improved sustainable land management and in particular governance.
Adoption by other land users / projects: Yes, few. Interest from cooperating universities (UFPE-Universidade Federal de Pernambuco, IFPE-Instituto Federal de Pernambuco).
Improved livelihoods / human well-being: Yes, little. No immediate impact, however the CA approach could potentially contribute to improved well-being.
Improved situation of disadvantaged groups: Yes, little. No immediate impact, however the CA approach could potentially contribute to an improved situation for socially and economically disadvantaged groups.
Poverty alleviation: No. No measurement possible.
Training, advisory service and research:
– Training effectiveness:
Teachers, planners, land users, school children / students, politicians / decision-makers, agricultural advisor / trainers : good
SLM specialists: excellent
– Advisory service effectiveness:
Technicians / conservation specialists, school children / students, politicians / decision-makers, planners, teachers, land users: good
Land/water use rights: None of the above in the implementation of the approach. Land use/water rights could be the topic of a CA. However, these are not of direct relevance for the application of the approach.
Long-term impact of subsidies: Irrelevant

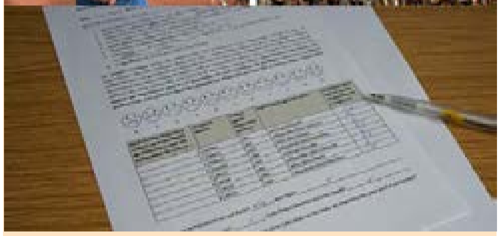
Conclusions and lessons learnt

Main motivation of land users to implement SLM: Affiliation to movement / project / group / networks; production; environmental consciousness, morale, health; Well-being and livelihoods improvement; prestige / social pressure.
Sustainability of activities: Yes the land users can sustain the approach activities without support. Knowledge acquired about a complex, perhaps previously non-transparent system and newly established contacts support future decision-making. In general CA is a flexible method that can be applied by any group, but preferentially mixed stakeholder groups.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Results can be used for the planning of regional development → Continued discussion of results are required.	One workshop cannot manage to convey the dynamics of a situation → Formulate recommendations for action and distribute a report to stakeholders
Space for interchange of ideas and establishing contacts → Maintain a list of actors and participants.	CA only visualizes the current situation. Different future scenarios over a given timespan can be presented only in a series of single CA visualizations → CA could lay the groundwork for scenario modelling approaches (e.g. Bayesian Networks).
Integrates different views of problems → Formulate recommendations.	Insufficient space for all to participate, topics covered in too little time. As more than one workshop is needed, the approach does not necessarily provide solutions in the end → Prepare goal-orientated workshops and finish a workshop by identifying potential solutions and formulating recommendations. I is important to well document and report on the workshops and distribute the reports to stakeholders.
Facilitates participation possibilities for stakeholders → Establish identical or similar workshops/events and facilitate participation processes.	
Allows expression and discussion of different views, knowledge integration, both inter- and transdisciplinary, characterised by an iterative and participative nature, able to detect complex situations and questions → better facilitate and encourage discussions among stakeholder during new and upcoming workshops	

Key reference(s): Rodorff V.et al. (2013a) Driving forces and barriers for a sustainable management of the Itaparica reservoir region - basic milestones towards a constellation analysis. In: Gunkel G. et al. (Eds.) (2013) Sustainable Management of Water and Land in Semiarid Areas. Editora Universitária UFPE, Recife, pp 2 • Rodorff, V., Siegmund-Schultze, M., Köppel, J., Gomes, E.T.A. (2015) Governança da bacia hidrográfica do rio São Francisco: Desafios de escala sob olhares inter e transdisciplinares. Revista Brasileira de Ciências Ambientais 36, 30-56.
Contact person: Verena Rodorff, Berlin Institute of Technology (Technische Universität Berlin), Environmental Assessment and Planning Research Group, Secr. EB 5, Straße des 17. Juni 145, 10623 Berlin, Germany; verena.rodorff@tu-berlin.de





left: Model and scenario development using Bayesian Network Approach (Photo: Liron Steinmetz)
right top: Stakeholder interview in a fruit cooperative. (Photo: Liron Steinmetz)
right bottom: Interview questionnaire. (Photo: Liron Steinmetz)

Bayesian Network Approach

Brazil - *Abordagem com Redes Bayesianas*

Assessment of the probability and effectiveness of management options or innovations to describe cause-effect-relationships and to make recommendations for action on sustainable land management in the Itaparica region in Northeast Brazil.

The study focus was on the determinants behind the adoption of innovations developed under a scientific project. The specific innovation analysed was intended to benefit both the environment and local smallholder farmers: namely cultivating a multi-purpose, low-growing, to the prevailing harsh semiarid environment well-adapted tree species (*Spondias tuberosa* L. – so called *umbuzeiro*). The assessment method was selected as it allows the combination of qualitative and quantitative data, and can be applied even in data-scarce situations. Moreover, it allows downscaling from a broad overview to small-scale management.

Knowledge is collected from different disciplines to support decision-making through the inter- and transdisciplinary approaches of constellation analysis and Bayesian networks. A Bayesian Network (BN) is a probabilistic graphical model that represents a set of variables (elements, nodes) and their conditional dependencies. There are three input components to a Bayesian Network: (a) a set of elements representing factors relevant to a particular environmental system or problem, (b) the links between these elements, and (c) the conditional probability tables (CPTs) behind each node (element) used to calculate the state of the node. Collected data and ratings are arranged in a hierarchical Bayesian Network model in Netica software (Netica 5.12 - freeware up to 15 nodes).

The creation of a Bayesian Network model is as follows: the objectives and necessary interventions for the innovation process aimed at sustainable management are characterized, with scientists arranging a conceptual diagram, including the mapping of elements. States of the nodes are determined through study of the literature and expert consultation (by scientists, stakeholders and experts on related topics). In a final step, a sensitivity analysis is performed on the Bayesian Network to highlight crucial nodes with the highest influence on objectives in order to derive actions to be recommended.

Stakeholder participation is the core process of designing Bayesian Networks. In pre-consultations stakeholders help identifying major influencing factors and relationships. Assessments are compiled in interview sessions enabling the states of the nodes to be quantified later. In this case study, the stakeholders were farmers, farmer-supporting institutions, and expert in soils, vegetation and crops.

Location: Pernambuco, Brazil, Itaparica Reservoir, Petrolândia
Approach area: > 10,000 km^2
Type of approach: project/programme based
Focus: Mainly on conservation with other activities
WOCAT database reference: A_BRA005en
Related technology: none
Compiled by: Verena Rodorff, Berlin Institute of Technology, Environmental Assessment and Planning Research Group, 10623 Berlin, Germany; verena.rodorff@tu-berlin.de
Date: 20th May 2014, updated June 2016

INNOVATE

Problem, objectives and constraints

Problems:
Low agricultural productivity and production, recurrent droughts. Little secured access to water. Almost no regeneration of endemic tree species. Increased degradation of the caatinga biome and its natural vegetation in the northeast of Brazil. Caatinga means “white forest” and is a xeric shrubland and thorn forest, which consists primarily of small, thorny trees that shed their leaves seasonally.

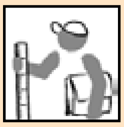
Aims / Objectives:
The principle of Bayesian Network modelling is the integration of multiple issues and system components, where information from different sources can be integrated, while also handling missing data and uncertainty. The outcome may be recommendations that support local management decision-making. As the method is strong in transdisciplinary knowledge integration, it has the potential to become one of the core methods in environmental management.

Constraints addressed

	Constraints	Treatments
Technical	Bayesian Network programmes need a licence. Questionnaires need to be easy and user friendly.	Use available free programmes. Use of visual aids such as smileys for evaluation to make questionnaire more comprehensible.
Workload	Work on and define clear objectives and model structure before developing the questionnaire.	Data collection through a review of literature and surveys. Discuss model structure with experts.
Financial	For stakeholders, financial support is necessary to implement innovations.	Potential for financial support could be through national small-scale farmer programs; suitable government-sponsored credit programs, public and governmental institutions such as bulk purchasers of agricultural commodities (for instance SEBRAE in Brazil).
Legal / land use and / water rights	Illegal cutting of native trees for biochar production.	Reinforcement of rules and regulations. The forest code prohibits cutting native trees. The native *umbuzeiro* tree is sacred for locals.

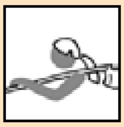
Participation and decision making

Stakeholders / target groups



SLM specialists / agricultural advisors

politicians / decision makers



land users, groups

Approach costs met by:

– International: German Federal Ministry of Education and Research (BMBF)	100%
Total	**100%**

Annual budget for SLM component: US$ < 2,000. Project funds covered all of the relatively low expenses; hypothetically the approach can be used almost free of charge.

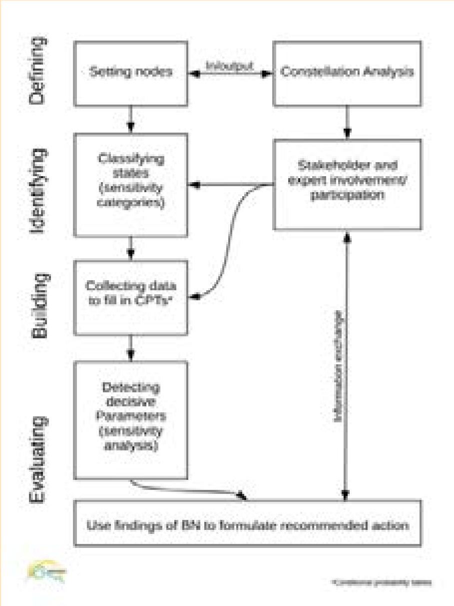
Decisions on choice of the Technology: The approach was initiated by scientists.
Decisions on method of implementing the Technology: There is still no formal decision by stakeholders on the technology and its implementation.
Approach designed by: International specialists.
Implementing bodies: International, local community / land users, local government (district, county, municipality, village etc.)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Passive	Interviews
Planning	None	None
Implementation	Interactive	Interviews
Monitoring/evaluation	Interactive	Interviews
Research	None	None

Differences between participation of men and women: No

Involvement of disadvantaged groups: Yes, great. Farmers of a resettlement community on dryland and representatives of the indigenous Pankararu tribe.



Organogram:
Simplified work flow of Bayesian Network (BN) showing different steps:
- Defining: apply or use already applied constellation analysis (see A_BRA003en) for information and visualization of node setting for the BN model and for stakeholder identification.
- Identifying: clarify objectives, implementation factors, interventions, intermediates and controlling factors. Give every node a state, e.g. date, temperature range, amount of precipitation, or a classification: high / low…
- Building: Collect data to fill the conditional probability tables (CPTs) behind every node. Prepare questionnaires, ask experts and conduct a literature search. Avoid too much states and no more than four nodes indicating the next node. Finish the model by entering all data in a programme (e.g. Netica).
- Evaluating: Compare different scenarios by changing the state of inputs (e.g. from low to high). Show a baseline (without changes), a most improved and least improved scenario to justify recommendations. Finally, hand over recommended actions to stakeholders.

(Liron Steinmetz and Verena Rodorff)

Technical support

Training / awareness raising: Training was provided for land users, field staff/agricultural advisors. Training was through demonstration areas, by workshops, site visits / farmer-to-farmer visits. Training focused on detecting decisive factors to develop an ideal scenario of implementation/ adoption by land users. For the participants it was interesting to participate in preparing a joint view of their “action space” - this is generally known in its constituent parts though not with its major interconnections and complex completeness. Participants especially acknowledged the value added of this.
Advisory service: To apply the BN approach for other innovations, a guideline for BN can be of help.

Research: Research was very important to this approach. Topics covered include sociology, technology, economics / marketing, ecology. Mostly on-station research but also on-farm research took place. Research on the situation of local action and governance was a major driver for the workshops. University project members prepared and held the workshops, while also interpreting and integrating results across a number of different workshops.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Voluntary
Input: None
Credit: Credit was not available
Support to local institutions: Yes, great support by training. Decisive factors for the adoption of innovations were identified, including favourable cultivation techniques for the *umbuzeiro* tree (e.g. soil additives).

Monitoring and evaluation

Monitored aspects	Methods and indicators
bio-physical	Regular measurements by project staff: Monitoring of *umbuzeiro* plantations on an experimental plot.
technical	Ad hoc observations by project staff, land users: Test plantations within family farmed land. Regular measurements by project staff: Monitoring of *umbuzeiro* plantations on an experimental plot.
socio-cultural	Regular observations by project staff, land users: the indigenous Pankararu tribe and smallholders involved.
economic / production	Regular observations by project staff, land users: Questionnaires. Regular measurements by project staff, land users: Calculated BN objective.
area treated	Regular observations by project staff: Selected innovation is limited to the area of caatinga vegetation.
no. of land users involved	Regular measurements by project staff: Number of participants in workshops and interviewees.
management of Approach	Regular observations by project staff: Feedback on approach by stakeholders, self-evaluation. Regular measurements by project staff, land users: Probability calculations based on the BN questionnaires

Changes as result of monitoring and evaluation: There were several changes in the approach. The iterative process of interviews of the BN approach leads to constant re-evaluation of the original network. There were no changes in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, great. The different scenarios tested under the BN highlighted the good probability of adoption, which then can support sustainable land management.
Adoption by other land users / projects: No. Unknown
Improved livelihoods / human well-being: Yes, great. The different scenarios tested under the BN highlighted the good probability of adoption, which can then benefit the livelihoods of adopters.
Improved situation of disadvantaged groups: Yes, moderate. The approach was conducted especially for small-scale farmers without sophisticated irrigation techniques, and also for the indigenous Pankararu tribe.
Poverty alleviation: Yes, little. Not immediately but a long-term influence is possible.
Training, advisory service and research:

- Training effectiveness:
  Agricultural advisors / trainers, politicians / decision-makers, land users, SLM specialists, planners: good
- Advisory service effectiveness:
  Technicians / conservation specialists, politicians / decision-makers, land users: good
- Research contributing to the approach's effectiveness:
  Greatly. BN's accuracy is closely dependent on the preceding research (existing literature data and quality of questionnaires filled).

Land/water use rights: None of the above in the implementation of the approach. Limited access to water within the study region was one of the main factors for assessing alternative agriculture methods via the BN approach. The approach did reduce the land/water use rights problem (moderately). The BN model offers alternative sources for soil additives where land use rights hinder availability.
Long-term impact of subsidies: Irrelevant to approach

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production; increased profitability, improve cost-benefit ratio; well-being and livelihoods improvement; environmental consciousness, morale, health; payments / subsidies.
Sustainability of activities: Yes the land users can sustain the approach activities without support. Lessons learnt (especially about the most favourable soil additive mixture) improved effectiveness of potential *umbuzeiro* tree cultivation. Stakeholder pool of BN-creation comprises business networking opportunities for land users.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
The combination of input variables from any given background is possible → It is recommended to use research results.	The statistical component of the Bayesian network approach can be hard to grasp for poorly educated stakeholder groups → Percentages of probability estimations can be translated into a visual representation (eg a gradual scale of emoticons).
Via Bayesian network changes to the modelled system can be tested. The space and potential effects of management options can be shown to decision-makers → Hand out results and show scenarios via presentations or reports	
Combining Bayesian networks with Constellation Analysis (see A_BRA003en) allows easy determination of major nodes of the model and supports the process of decision-making for sustainable land management activities; methods proved to be very transdisciplinary → Combination with Constellation Analysis helps to identify specific actors and to show complex situation as well as interest of stakeholders.	

Key reference(s):
http://www.innovate.tu-berlin.de/v_menue/subprojects/sp7_decision_support_approach_and_project_coordination/sp7_rm1_decision_support_approach/parameter/en/
• Rodorff V., Steinmetz L., Siegmund-Schultze M., Köppel J. (2015) Using Bayesian networks to depict favouring frame conditions for sustainable land management: Umbuzeiro-tree planting by smallholders in Brazil. Session: Methods, tools and impact applications. Tropentag 'Management of land use systems for enhanced food security - conflicts, controversies and resolutions', September 16 – 18, 2015, Humboldt-Universität zu Berlin, Berlin, Germany.
Contact person: Verena Rodorff, Berlin Institute of Technology (Technische Universität Berlin), Environmental Assessment and Planning Research Group, Secr. EB 5, Straße des 17. Juni 145, 10623 Berlin, Germany; verena.rodorff@tu-berlin.de

left: Overview of the drip irrigation system under plastic mulch. (Photo: Shamaila Zia-Khan). **right:** Detailed view of the system. The large black hoses provide the main water supply for the whole irrigation system. (Photo: Shamaila Zia-Khan).

Drip irrigation under plastic mulch for cotton production in Xinjiang province, China

China - 膜下滴灌

Drip irrigation under plastic mulch, associated with drainage, to reduce water demand and improve cotton yields in Xinjiang Province, China.

The dry climate and the long hours of sunshine make Xinjiang especially suitable for production of high quality cotton, and as a result some 40% of China's cotton is grown here. But there are two main problems: shortage of water and salinization of the soil. Farmers who use the traditional flood irrigation method, and don't have a drainage system, tend to abandon their fields when they become too saline - and then they look for new land to cultivate. A combination of mulching and drip irrigation can be very effective but still needs careful management. Drip irrigation helps to save water for farmers - and for the environment. But it is still very important to install a drainage system to dispose of surplus water in order to reduce the risk of salinization of the soils. Every four cotton rows are covered with transparent polyethylene film and as a result approximately 80% of the ground surface is covered by the plastic mulch. Plastic mulch and drip lines are placed with a specially equipped tractor.

Low temperatures and dry soil at sowing, in combination with soil salinity, hinder early plant growth. Plastic mulching increases soil temperature, reduces the need for irrigation, and also helps control salinity in the root zone and suppresses weeds, thereby increasing yields by 10–30% (and improving quality also) (Wang, R. et al., 2011). In the first stages after sowing the climate is particularly cold. With plastic mulching the cotton plants can be sown earlier, because the soil will not cool down during the night as much as without plastic mulch.

For the establishment of the new technology of drip irrigation under plastic mulch, it is simultaneously essential to install a drainage system to avoid raising the groundwater level and causing salinity. For the installation of the drip lines, the transparent plastic film and the seeding, a tractor and a special tool for the installationis needed: one acre can be installed in a day. After the emerging of the cotton plants, holes must be cut in the plastic film so that the cotton plants can emerge. After harvesting, the drip lines and the plastic film must be collected and recycled. If the plastic is left behind it will pollute the soils and injure livestock if they eat it. Furthermore plastic residues in the soil can reduce subsequent yields, as roots are physically inhibited. After the collection of the plastic residues, if there is no adequate drainage system, the field needs to be flooded to flush the salt layer, which has accumulated below the root zone, deeper into the soil. If the field is not flooded the salt will negatively affect the next years' cotton plantation.

Southern Xinjiang is an arid region with 50 to 90 mm per year. Most precipitation occurs between June and August. It is classified as a temperate cold desert climate. For drip irrigation under plastic mulch, it is principally surface water that is used, which is delivered to the field via channels from reservoirs to the fields. The reservoirs are filled in summer with the floods along the Tarim River. The untreated surface water is of poor quality - for agricultural use only. For drip irrigation, the water needs to be treated to avoid blocking the drip outlets. The overall technology is expensive, and only land user groups and communities can afford the machines and the materials.

Location: China / Xinjiang Province
Region: Tarim River Basin
Technology area: > 10,000 km^2
Conservation measure: management
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago); externally / introduced through project, recent (<10 years ago)
Land use type: cropland: annual cropping (cotton); forest: natural vegetation (before)
Climate: arid, temperate
WOCAT database reference: T_CHN057en
Related approach: none
Compiled by: Christian Rumbaur, Technical University of Munich, Chair of Hydrology and River Basin Management, 80333 München, Christian.rumbaur@tum.de
Date: 14th May 2015, updated August 2016

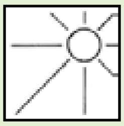
Classification

Land use problems: Water use conflicts between agriculture and natural vegetation, soil salinization, desertification (expert's point of view). Soil salinization and water shortage (land user's point of view).

Land use

cropland: annual cropping , forests / woodlands: riparian forest / natural vegetation (before), full irrigation

Climate



arid

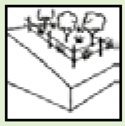
Degradation

chemical: salinization / alkalinization

wind erosion

water degradation: aridification

Conservation measure



management: change of management / intensity level, major change in timing of activities

Stage of intervention

- □ Prevention
- ■ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative
- □ Experiments / research
- □ Externally introduced
- ■ Introduced by state specialists: 10-50 years ago

Level of technical knowledge

- ▒ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - Human induced: soil management, crop management (annual, perennial, tree/shrub), deforestation / removal of natural vegetation (incl. forest fires), over abstraction / excessive withdrawal of water (for irrigation, industry, etc.).
Direct causes - Natural: wind storms / dust storms, droughts.
Indirect causes: population pressure, land tenure, poverty, education, access to knowledge and support services.

Main technical functions:
- increase of water use efficiency
- increase of biomass (quantity)
- improvement of ground cover / reduces evapotranspiration

Secondary technical functions:
- improvement of surface structure (crusting, sealing)
- increase / maintain water stored in soil

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- □ 250-500
- ■ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- ■ 1000-1500
- ■ 500-1000
- □ 100-500
- □ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- ■ valley floors

Slope (%)

- ■ flat
- ▒ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- □ 0-20
- □ 20-50
- □ 50-80
- ■ 80-120
- ■ >120

Growing season(s): 220 days(March to October with irrigation)
Soil texture: coarse / light (sandy), medium (loam)
Soil fertility: medium, low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: high, medium
Ground water table: < 5 m, 5 - 50 m
Availability of surface water: good
Water quality: poor drinking water

Tolerant of climatic gradual change and extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, wind storms / dust storms, droughts / dry spells, decreasing length of growing period
Sensitive to climatic gradual change and extremes: heavy rainfall events (intensities and amount), floods
If sensitive, what modifications were made / are possible: not to use this technology in flood-prone areas

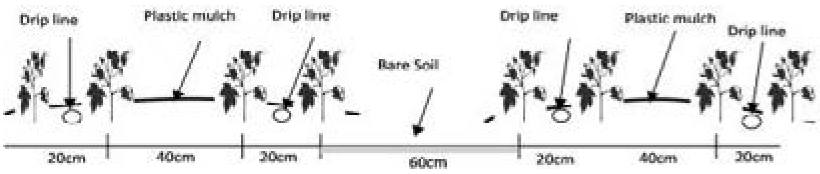
Human Environment

Cropland per household (ha)

■	<0.5 (household)
□	0.5-1
□	1-2
□	2-5
■	5-15 (enterprise)
□	15-50
□	50-100
□	100-500
□	500-1,000
□	1,000-10,000
□	>10,000

Land user: groups / community, medium scale land users, average land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: > 4%
Land ownership: state
Land use rights: leased (all the land belongs to the state. Farmers have the right to use the land for 70 years).
Water use rights: leased
Relative level of wealth: very rich, which represents 5% of the land users; 10% of the total area is owned by very rich land users

Importance of off-farm income: less than 10% of all income is in form of remittances: Farmers who have not implemented the drip irrigation under plastic mulch also generate off-farm income.
Access to service and infrastructure: moderate: technical assistance, employment (e.g. off-farm), drinking water and sanitation, financial services; high: health, education, market, energy, roads & transport
Market orientation: commercial / market
Mechanization: manual labour
Livestock grazing on cropland: yes



Technical drawing

There are double rows of cotton 20 cm apart, with a drip line between. 40 cm then separates each double row. Two double rows are covered by one length of plastic mulch. There is a small strip of bare soil between each length of plastic mulch. Mulch covers around 80% of the soil surface (Shamaila Zia-Khan).

Implementation activities, inputs and costs

Establishment activities

1. Tractor for field preparation
2. Initial drip line and plastic mulch installation

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	3.00	100%
Equipment		
– tractor use	5.00	100%
Other		
– transparent plastic mulch	32.00	50%
– black drip lines	380.00	50%
TOTAL	**420.00**	**50.59%**

Maintenance/recurrent activities

1. Ploughing and levelling of field.
2. Installation of drip lines, plastic mulch and seeding of (cotton) plants.
3. Making holes for the (cotton) plants in the plastic mulch.
4. Maintaining hoses
5. Irrigation
6. Removal of the drip lines and the plastic mulch
7. Flooding after harvest/ flushing or salt into lower soil layers

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	5.00	100%
Agricultural		
– seeds	90.00	100%
– irrigation and flooding water (pumps)	8.00	100%
Other		
– transparent plastic mulch	32.00	100%
– black drip lines	380.00	100%
TOTAL	**515.00**	**100%**

Remarks:
The costs for the machine, the plastic hoses and the plastic mulch are calculated above are for 1 ha and were calculated on the basis of 2013 (subsequently costs have risen). Water price: 0.019 CNY/m^3. Farmers need 3000 m^3 per ha.

Assessment

Impacts of the Technology	
Production and socio-economic benefits	**Production and socio-economic disadvantages**
+ reduced demand for irrigation water + increased crop yield	− increased expenses on agricultural inputs − increase of salinization below root zone
Socio-cultural benefits	**Socio-cultural disadvantages**
	− worse situation of disadvantaged groups
Ecological benefits	**Ecological disadvantages**
++ reduced evaporation + improved soil cover + reduced soil loss from wind erosion	− increased salinity, if no drainage system is installed in the field
Off-site benefits	**Off-site disadvantages**
+ reduced wind transported sediments	
Contribution to human well-being/livelihoods	
+ Applying this technology saves farmers water and thus money.	

Benefits/costs according to land user	Benefits compared with costs	short-term:	long-term:
	Establishment	slightly negative	positive
	Maintenance/recurrent	slightly negative	positive

Acceptance/adoption: 100% of land user families have implemented the technology with external material support. The government gives subsidies to the farmers to install the drip irrigation under plastic mulch. No land user families have implemented the technology voluntarily. The government's strategy is to spread the technology over the whole region by giving subsidies to the farmers.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
It helps to save water during the growing period and thus helps to reduce conflicts between upstream and downstream farmers → The technology (drip + mulch) needs to be supplemented by installing a drainage system in the fields otherwise there will be a build-up of salinity and farmers will abandon land and move on.	Salinization of the soils is increasing The consequence is that the fields are flooded after harvest in November/December to leach out the salt. The water used for drip irrigation plus the water to flush the salts to lower soil layers add up to almost the same amount as if farmers were using the original flood irrigation technology → drainage system in the fields required
Helps to save water thus saves costs → It is subsidised by the government	

Key reference(s): Zia-Khan,S., Spreer, W., et al. (2015) Effect of dust deposition on stomatal conductance and leaf temperature of cotton in Northwest China. Water 2015, 7, 116-131; doi: 10.3390/w7010116. www.mdpi.com/journal/water open access
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left: Apocynum plant at flowering (Photo: Christian Rumbaur)
right: Apocynum stand in Xinjiang Province, China (Photo: Niels Thevs)

Apocynum planting to protect and profit from saline soils in the Tarim River Basin, north-west China

China - 罗布红麻 and 罗布百麻

Plantation of *Apocynum pictum* and *Apocynum venetum* as protective and profitable indigenous plants - on soils made saline through irrigation of cotton without adequate drainage.

The natural ecosystems in north-west China, especially in Xinjiang Province, are dominated by steppes, semi-deserts and desert. Riparian forests along the Tarim River Basin have been reduced and degraded by the expansion of irrigated agriculture since the 1950s. The main crop planted is cotton. In the arid temperate cold desert climate, precipitation is very low and evaporation high. The only water source for the region is the Tarim River. Xinjiang is being promoted to become the main cotton production area of China, especially in the upper reaches of the Tarim River, and reservoirs with a large irrigation infrastructure have been established. Farmers water their fields with flood and drip irrigation. But most of the fields have no drainage system. With the high evaporation and the capillary rise of the shallow groundwater, salts dissolved in the water accumulate on the soil surface and in the soil. This salinization makes the fields unusable for cotton production and are abandoned as farmers move on. These barren saline soils are prone to wind erosion, as almost no plants can grow on them. Large-scale desertification is the result.

To halt desertification the barren saline soils need to be protected by vegetation to avoid soil loss by wind. But if this can be done through vegetation that yields an income then the advantage is double: a win-win situation. *Apocynum venetum* and *Apocynum pictum* are indigenous and both are drought and salt tolerant. They are phreatophytes: deep-rooted plants that tap groundwater or the soil layer just above the water table. *A.venetum* and *A. pictum* are rhizomatous perennials – and importantly they are cash crops too. Fibre from the stems are used to produce textiles, though the extraction process is time and labor consuming. The advantage of apocynum yarn is that it has antibacterial properties. The leaves and flowers are also sold and used to produce tea which is a Traditional Chinese Medicine (TCM) that reduces blood pressure. On a per hectare basis, the stem generates a potential income of US$ 3,650, the leaves US$ 1,995, and the flowers US$ 1,815: nevertheless the market for apocynum products is small. In Xinjiang most of the apocynum plantations are under commercial large-scale farmers. They have the capital to deal with the costly establishment of apocynum.

Fields on which apocynum is sown should have a groundwater level not deeper than 2m. Nevertheless the soil should be well-drained: best is a sandy loam. Waterlogged, calcareous, clayey soils are not suitable. Apocynum can withstand periods of water inundation; however, prolonged submergence or waterlogging inhibits its growth. The topsoil under apocynum is often saline, reaching salt contents of up to 20%. Apocynum can grow on sites with a pronounced surface salinization, as long as the subsoil and the groundwater are not strongly salinized. There are two methods of planting apocynum: by seed or by vegetative means. While irrigation helps establishment and good yields, this is at a much lower level than for cotton. In conclusion, *A.venetum* and *A. pictum* provide profitable options on saline soils, grow with minimal irrigation, and protect the land against wind erosion.

Location: China / Xinjiang Province
Region: Tarim River Basin
Technology area: > 10,000 km^2
Conservation measure: vegetative, management
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: developed naturally, traditional (>50 years ago)
Land use type: cropland: annual cropping (before), wastelands, deserts (currently), tree and shrub cropping (after)
Climate: arid, temperate
WOCAT database reference: T_CHN058en
Related approach: none
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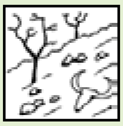
Date: 14th March 2014, updated August 2016

SuMaRiO

Classification

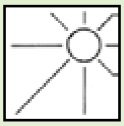
Land use problems: Salinization, desertification, mismanagement of cotton monoculture, inadequate drainage under irrigation, abandonment of degraded land (expert's point of view). Water scarcity, salinization, land use rights (land user's point of view).

Land use



cropland: annual cropping / cotton monoculture, (before); wastelands, deserts (current); cropland: tree and shrub cropping (after)

Climate

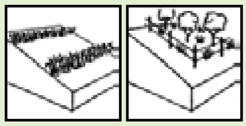


arid

Degradation

soil erosion by wind: loss of topsoil; chemical soil deterioration: salinization; biological degradation: reduction of vegetation cover/diversity decline

Conservation measure



vegetative: tree and shrub cover; management: change of land use type

Stage of intervention

- □ Prevention
- □ Mitigation / Reduction
- ■ Rehabilitation

Origin

- ▒ Land user's initiative: 10-50 years ago
- □ Experiments / research
- □ Externally introduced
- ■ Naturally: traditional (>50 years ago)

Level of technical knowledge

- ▒ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - Human induced: soil management, crop management (annual, perennial, tree/shrub)
Direct causes - Natural: wind storms / dust storms, droughts
Indirect causes: population pressure, land tenure, education, access to knowledge and support services

Main technical functions:
- improvement of ground cover
- stabilisation of soil
- promotion of vegetation species and varieties (quality, eg. palatable fodder)

Secondary technical functions:
- reduction in wind speed

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- □ 250-500
- ■ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- ■ 1000-1500
- ■ 500-1000
- □ 100-500
- □ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- ■ valley floors

Slope (%)

- ■ flat
- ▒ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- □ 0-20
- □ 20-50
- □ 50-80
- ■ 80-120
- ■ >120

Growing season(s): 220 days (March to October with irrigation)
Soil texture: coarse / light (sandy), medium (loam)
Soil fertility: medium, low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: high, medium
Ground water table: < 5 m, 5 - 50 m
Availability of surface water: good
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic gradual change and extremes: seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, droughts / dry spells
Sensitive to climatic gradual change and extremes: floods
If sensitive, what modifications were made / are possible: no planting of apocynum in the flood prone areas

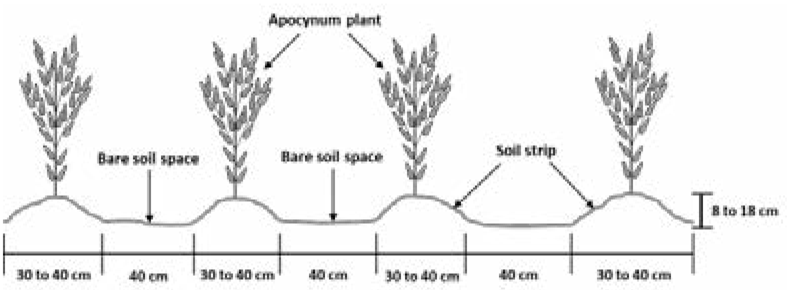
Human Environment

Cropland per commercial enterprise (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
■ (selected)	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Land user: groups / community, medium scale land users, average land users, mainly men
Population density: 10-50 persons/km^2
Annual population growth: > 4% in Xinjiang province
Land ownership: state
Land use rights: leased (all the land belongs to the state. Farmers have the right to use the land for 70 years).
Water use rights: leased.
Relative level of wealth: 30% of the total area is owned by rich land users, who represent 20% of the land users; 10% of the total area is owned by very rich land users, who represent 5% of the land users

Importance of off-farm income: less than 10% of all income: planting apocynum brings high income to the farmers.
Access to service and infrastructure: moderate: moderate: technical assistance, employment (eg. off-farm), drinking water and sanitation, financial services; high: health, education, market, energy, roads & transport
Market orientation: regional and outer-regional markets for Traditional Chinese Medicine (TCM), textile producing market
Mechanization: machinery: tractors, cultivators, harvesters
Livestock grazing on cropland: no
Types of other land: wastelands / deserts / glaciers / swamps



Technical drawing: Apocynum planted in a levelled field with strips of 8 to 18 cm height and 30 to 40 cm width with 40 cm space between each strip.

Implementation activities, inputs and costs

Establishment activities

1. Manuring (3,700 to 5,000 kg /ha) and ploughing
2. Site establishment / preparation
3. Planting of seedlings/ root cuttings/ transplants: most suitable time mid-April to May
4. Irrigation at establishment (10,000 to 12,000 m³ / ha)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	20.00	100%
Equipment		
– machine use (16 h/ ha)	12.00	100%
Agricultural		
– seeds and plastic bags	250.00	100%
– seedlings	618.00	100%
– manure (56’000 kg/ha)	3200.00	100%
– irrigation water fees	460.00	100%
TOTAL	**4560.00**	**100%**

Maintenance/recurrent activities

1. Weeding and irrigation labour (684 US$ / vegetation period and ha
2. Fertilizer application (45 to 75 kg of NPK / ha)
3. Irrigation (4,000 - 5,600 m³ / ha and year)
4. Harvesting
5. Transport of harvest

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour		
– irrigation and weeding	684.00	100%
– harvesting	340.00	100%
Equipment		
– machine use and transport	21.00	100%
Agricultural		
– water fee	2280.00	100%
– fertilizer	620.00	100%
TOTAL	**3945.00**	**100%**

Remarks: Costs were calculated for 2015, per hectare. Labour has become more expensive over the last few years. In the beginning (first two years) cultivation of apocynum is very labour and input intensive. After 1.5 to 2 years the plants can be harvested for the first time. The price for the products of apocynum (leafs and stems) are very high. Direct seeding as compared to vegetative propagation is the most labour-saving method to cultivate apocynum.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ diversification of income sources	−− limited market for apocynum fibre for textile production
++ reduced risk of production failure	− limited market for Traditional Chinese Medicine (TCM)
++ reduced demand for irrigation water	− increased expenses on agricultural inputs / high establishment costs
++ increased farm income (US$ 7,500 per hectare)	− increased labour constraints
++ increased production area and product diversification	
+ increased crop yield and firewood production	

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge	−− only rich farmers can grow apocynum as they can afford to pay the inputs (inequity).
+ improved cultural opportunities	
+ increased recreational opportunities (blooming flowers)	

Ecological benefits	Ecological disadvantages
++ improved soil cover	− decrease water quality – pollution of ground water by fertilizers
++ reduced soil loss	− reduced biodiversity – danger that apocynum becomes a monoculture
+ increased water quantity and soil moisture	
+ improved excess water drainage	
+ reduced wind velocity	
+ increased above and below ground C	

Off-site benefits	Off-site disadvantages
+ reduced groundwater river pollution	
+ reduced wind transported sediments	

Contribution to human well-being/livelihoods

+++ The technology improves livelihood, as the income generated is quite high.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	very positive
Maintenance/recurrent	slightly negative	very positive

Acceptance/adoption: 100% of land user families have implemented the technology voluntary. Most of the plantations belong to the richer farmers. They sell the leaves of apocynum to the pharmaceutical companies for Traditional Chinese Medicine (TCM). There is little trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Both species can grow without intensive irrigation, because they use groundwater. Furthermore, they can withstand higher soil salinization levels than cotton → The plantations could be made more efficient by analyzing water requirements and improving water use efficiency so as to reduce irrigation without decreasing yields.	Difficult process to extract fibre from the stems → New technology needs to be developed.
Both species can provide an income to local people - fibre and leaves for medicinal products or tea - under conditions which are unfavorable to grow crops under irrigation. → Promote apocynum on saline wastelands and subsidize the establishment of the plantations. Explore further markets and promote the products.	Small market → New uses need to be explored to expand the market.
Through apocynum plantations wastelands are reclaimed → Highlight the potential to reduce wind erosion and 'dust bowls'.	High investment in the beginning of the plantation → Planting of apocynum should be subsidized.

Key reference(s): N Thevs et al. (2012) *Apocynum venetum* L. and *Apocynum pictum* Schrenk (Apocynaceae) as multi-functional and multi-service plant species in Central Asia: a review on biology, ecology, and utilization. Journal of Applied Botany and Food Quality 85, 159-167.

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left: Rubber plantation with thriving undergrowth – no herbicides are used for maintenance (Hainan Island, China). (Gerhard Langenberger)
right: Taking care of an underplanted *Taxus mairei* seedling in a rubber plantation in the Naban River Watershed National Nature Reserve, Xishuangbanna, China. (Gerhard Langenberger)

Integrating native trees in rubber monocultures

China 减缓单一橡胶种植的负面环境影响：关于橡胶与当地树种混种并结合杂草管理的生态种植研究

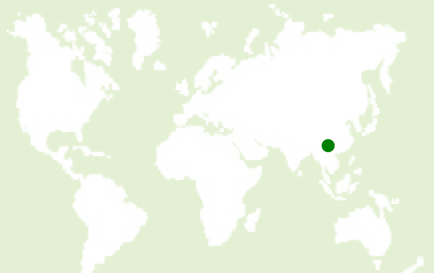
The technology combines the integration of native tree species into rubber monocultures with changed weed management to mitigate negative environmental impacts and to provide alternative income options for farmers.

Natural rubber is a crucial renewable resource produced from the tree *Hevea brasiliensis*. Production is largely based on monoculture, often associated with chemical-based clean-weeding. This causes environmental problems such as loss of biodiversity, pesticide pollution and erosion of topsoil. The SLM-technology aims at mitigating negative impacts by interplanting the rubber with native tree species which have economic potential of their own. Changes in weed management are part of the package also.

Native (indigenous) tree species are integrated into mature rubber plantations. Criteria for species selection are: a) adapted to environmental conditions; b) shade tolerant; c) vertical growth not affected by light; d) conservation value; e) economic potential; f) easy to manage. Rubber trees are usually planted in rows at a spacing of 6-8 m, and an intra-row distance of 2.5 to 3 m. The native trees are planted between the rubber rows. The plantation should be mature as the canopy will have reached its highest density, and weed competition is naturally suppressed. The spacing of the native trees needs to be adapted to their growth potential and intended usage. After planting, regular monitoring is necessary to identify pests or diseases. The following species were selected for demonstration sites: 1) *Parashorea chinensis*, a valuable timber tree, 2) *Taxus mairei*, a multi-purpose tree, providing good timber but also an anti-cancer drug, taxol, and 3) *Nyssa yunnanensis*, selected for its conservation value. At the end of the economic life span of the rubber trees (about 30 years) there will be several options, but there are three main ones. First the rubber plantation can be replanted, although the harvest of the *Parashorea chinensis* trees would be premature. The *Taxus mairei* trees could be maintained through a new plantation cycle. Second, both, the rubber and the intercropped trees could be maintained for future timber and taxol production. Third, the plantation could be transformed into a sustainable forest managed scheme where the rubber trees are extracted step by step and the intercropped trees maintained for their intrinsic value.

Procedures for the selection and planting of the indigenous tree species are crucial. Identification should be based on suitability for the climate and soil as well as economic potential. The raising of tree seedlings requires experience and nursery propagation by experts might be required. Only healthy seedlings should be used. Planting should take place during rainy periods. Potted seedlings are better than bare-rooted seedlings since they establish better. Generally, weed management (if necessary) should shift from herbicide application to mechanical weeding. Grass competition needs to be avoided in any case! Controlled cover of natural undergrowth will reduce erosion and promote water infiltration.

The implementation site for the trials is located in Xishuangbanna Prefecture, Yunnan Province, SW China. The original vegetation was tropical rain and monsoon forest, but now there is a rich mosaic of different land-use and vegetation types. The whole region is exceptionally species rich and part of the Indo-Burma-Biodiversity Hotspot.



Location: Xishuangbanna Dai Autonomous Prefecture, Yunnan Province, PR China
Region: Naban River Watershed National Nature Reserve
Technology area: 0.03 km^2
Conservation measure: vegetative, management
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago); review on available knowledge on rubber management and history (10-50 years ago)
Land use type: cropland: tree and shrub cropping (monocultures) (current); forests / natural vegetation (before), agroforestry (after)
Climate: subhumid, subtropics
WOCAT database reference: T_CHN056en
Related approach: A_CHN054en (Scientist-practitioner communication for sustainable rubber cultivation in China)

Compiled by: Gerhard Langenberger, University of Hohenheim, Institute of Agricultural Sciences in the Tropics, 70593 Stuttgart, Germany. langenbe@uni-hohenheim.de

Date: 12th February 2012, updated June 2016

Classification

Land use problems: Large-scale expansion of rubber monocultures results in the loss of topsoil and siltation of streams with respective consequences for CO_2 emissions (increased), soil degradation, water quality and stream ecology. The excessive application of agrochemicals adds to these problems. The monoculture practice combined with clean weeding results in plant biodiversity loss. The related simplification of habitat structures also leads to a considerable decline in animal biodiversity (expert's point of view). The focus of land users is primarily on sustainable income, and their environmental concerns mainly relate to water provisioning (land user's point of view). In the farmers view: "*The biggest environmental problem is water quantity. Rubber sucks out a lot of water, therefore we do have a water scarcity problem*". Farmers are aware of the contamination of drinking water due to the use of pesticides and herbicides in the rubber plantations.

Land use

tree and shrub cropping (current); forests / natural vegetation (before) agroforestry (after) rainfed

Climate

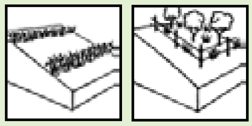
subhumid

Degradation

erosion by water: loss of topsoil / surface erosion

biological degradation: reduction of vegetation cover, loss of habitats, quality and species composition /diversity decline

Conservation measure



vegetative: tree and shrub cover

management: change of intensity level

Stage of intervention

- Prevention
- Mitigation / Reduction
- Rehabilitation

Origin

- Land user's initiative
- Experiments / research: recent (<10 years ago)
- Externally introduced
- Review on available knowledge on rubber management and history: 10-50 years ago

Level of technical knowledge

- Agricultural advisor
- Land user

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires)
Indirect causes: poverty / wealth, inputs and infrastructure, governance / institutional

Main technical functions:
- control of dispersed runoff: retain / trap
- stabilisation of soil (eg by tree roots against landslides)
- increase in organic matter
- increase of infiltration
- promotion of vegetation species and varieties (quality, eg palatable fodder)

Secondary technical functions:
- improvement of surface structure (crusting, sealing)
- improvement of topsoil structure (compaction)
- increase / maintain water stored in soil
- increase of groundwater level / recharge of groundwater

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Growing season(s): 270 days(April - December)
Soil texture: medium (loam), fine / heavy (clay)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: n/a
Availability of surface water: good
Water quality: poor drinking water
Biodiversity: high

Tolerant of climatic gradual change and extremes: temperature increase, seasonal rainfall increase, heavy rainfall events (intensities and amount)
Sensitive to climatic gradual change and extremes: seasonal rainfall decrease, droughts / dry spells, decreasing length of growing period, cold spells
If sensitive, what modifications were made / are possible: the above assessment is based on the fact that the native tree species are adapted to tropical conditions. Therefore, the species should be less affected by high temperatures and increasing rainfall, but might still be sensitive to droughts. Nevertheless, there is no experience or data as yet.

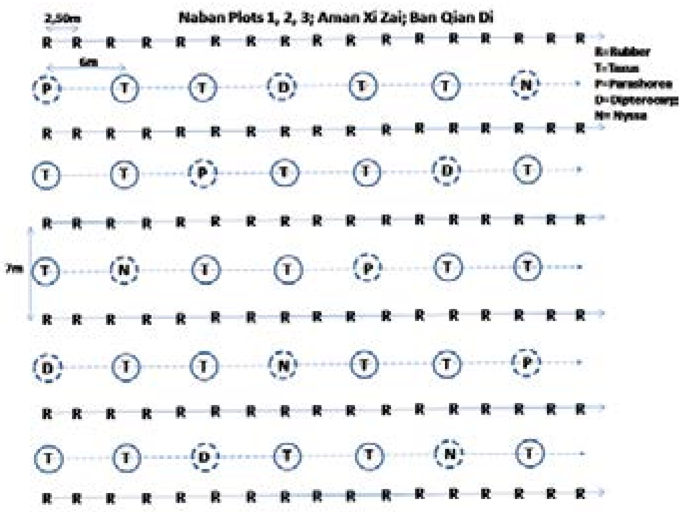
Human Environment

Cropland per household (ha)

<0.5
0.5-1
1-2
2-5
5-15
15-50
50-100
100-500
500-1,000
1,000-10,000
>10,000

Land user: individual / household, small-scale land users, leaders / privileged, mainly men
Population density: 10-50 persons/km^2
Annual population growth: < 0.5%
Land ownership: state
Water use rights: complex depending if water is on village land or not
Land use rights: mainly individual
Relative level of wealth: farmers have been well off in the past, currently they are under pressure due to the very low rubber prices

Importance of off-farm income: 30%
Access to service and infrastructure: moderate: technical assistance, employment (e.g. off-farm), drinking water and sanitation; high: health, education, market, energy, roads & transport
Market orientation: commercial / market
Mechanization: manual labour
Livestock grazing on cropland: no



Technical drawing

The concept is based on rubber planted in rows of ca. 7 m and within rows of ca. 2.5 to 3 m. Intercropping takes place between the rows. However farmers often plant at a higher density which requires an assessment of the light / shade conditions. At too high a density the light conditions can be too poor for intercropping even for shade tolerant forest trees. In this case study, the distance within a row of the intercropped trees was set at 6 m, due to the ecological characteristics of the selected tree species. Thus, in this case, the choice was for a higher density of Taxus (bold circles) which is well known for its slow growth and the two other tree species were integrated at a wider distance (dotted circles) (G. Langenberger).

Implementation activities, inputs and costs

Establishment activities

1. Seedling acquisition and transport
2. Planting of seedlings in rainy season
3. Weed management with brush cutters.

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	80.00	100%
Equipment		
– machine use	80.00	0%
– tools	8.00	100%
Agricultural		
– seedlings	2400.00	0%
TOTAL	**2568.00**	**3.5%**

Maintenance/recurrent activities

1. Control of pests and diseases

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	96.00	100%
TOTAL	**96.00**	**100%**

Remarks: Seedling costs are the major cost factor. Since the selected species are unusual and are not readily available they are very expensive. Because *Taxus* is also a medicinal plant, this might also have influenced the price. All other costs are practically negligible. In this case the establishment of a nursery might considerably reduce the costs, since propagation (at least of *Taxus* and *Parashorea*) is easy if the seeds can be acquired. The costs are based on the establishment of 3 demonstration plots of ca. 1 ha each. It should be possible to considerably reduce the costs by producing seedlings on site.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
	− increased labour constraints

Socio-cultural benefits	Socio-cultural disadvantages
+++ improved conservation / erosion knowledge	

Ecological benefits	Ecological disadvantages
+++ reduced surface runoff +++ improved soil cover ++ increased water quality ++ increased biomass and above ground carbon	

Off-site benefits	Off-site disadvantages
+++ reduced downstream siltation +++ improved buffering / filtering capacity (by soil, vegetation, wetlands) + reduced groundwater / river pollution reduced erosion and pesticide inputs contribute to water security and maintain stream ecology	

Contribution to human well-being/livelihoods

Since we are still at an experimental level there isn't yet any experience.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance/recurrent	positive	very positive

The establishment costs for the demo-sites have been very high, but could be considerably reduced if adopted by more farmers. The assessment above therefore needs verification in the course of time.

Acceptance/adoption: Three families have been approached for testing in different areas of the Xishuangbanna prefecture. They have been supported by external material support. There is little trend towards (growing) spontaneous adoption of the technology, although there is an increasing interest. But due to the lack of experience and the lack of affordable and accessible seedlings farmers were hesitant.

Concluding statements

Strengths and → how to sustain/improve

The technology offers considerable long-term advantages to farmers. After establishment it doesn't require much labour → A proper and sustainable extension service is required to accompany the development of the technology. Government subsidies for establishment of seedlings would certainly increase the number of farmers adopting the concept.

Additional income options → It diversifies the product portfolio with good options for additional income in the future.

Weaknesses and → how to overcome

The technology is based on a long-term perspective and thus favours farmers who have a such an outlook. But farmers with little land usually think short-term → The current trend of rural-urban migration will support the technology since it can be easily combined with off-farm work. According to SURUMER findings off-farm income already contributes about one third of the overall household income in the rubber growing areas.

Current establishment costs are very high due to the lack of a seedling market → If the technology becomes known and popular, more nurseries will produce seedlings which will reduce costs. Alternatively, farmers might establish their individual (or community) nurseries.

The technology requires considerable knowledge about tree ecology and tree breeding → There should be extension officers at the local agricultural or forestry bureaus supporting farmers.

High investment costs → Government subsidies

Time until first returns can be expected. 5-10 years for taxol production)

Key reference(s): Ahrends, A. et al. (2015) Current trends of rubber plantation expansion may threaten biodiversity and livelihoods. Global Environ Change, 34, 48-58. • Langenberger, G. et al. (2016) Rubber intercropping: a viable concept for the 21st century? Agrofor Syst, 1-20. • Liu, H. et al. (2016) Impact of herbicide application on soil erosion and induced carbon loss in a rubber plantation of Southwest China. CATENA, 145, 180-192.
Contact person(s): Gerhard Langenberger, University of Hohenheim, Institute of Agricultural Sciences in the Tropics, 70593 Stuttgart, Germany, langenbe@uni-hohenheim.de • Feng Liu, Naban River Watershed National Nature Reserve Bureau, Jinghong, China, 24098934@qq.com

left: Outdoor activities during the 2nd regional workshop with participants from prefecture administration, research institutes, companies, and from the research project in Mandian village, Naban River Watershed National Nature Reserve (Wang, Jue)
right: A focus group discussion with innovative farmers and village heads from villages at Mandian Education Center. (Wang, Jue)

Scientist-practitioner communication for sustainable rubber cultivation in China

China

Establishing communication between scientists and practitioners to improve sustainable rubber cultivation in Yunnan, China

The Sino-German project "SURUMER: Sustainable rubber cultivation in the Mekong Region" is identifying appropriate, stakeholder-validated concepts for sustainable rubber cultivation in Xishuangbanna prefecture, South-west China. In order to at least begin to implement solutions for problems arising from monoculture, project partners from five German and seven Chinese research institutes and practitioner partners are testing a holistic approach. This combines communication activities (bilateral, as well as groups, mainly through workshops) with scientific analysis to enhance interaction and collaborative learning between practitioners and researchers.

The approach comprises a pragmatic combination of discourse instruments such as direct communication amongst partners, bilingual information material, newsletters, focus groups, and a series of workshops with key stakeholders. One of its main elements is participatory scenario development - including discussions on problem situations, priorities regarding ecosystem services, and trade-offs in different land use strategies.

During the first three-year phase of research, ecosystem functions and services were assessed and quantified. This phase of situation analysis had a clear multidisciplinary focus amongst researchers (topics as widely varied as carbon sequestration, pollination, and household economy). The next phase attempted to integrate findings from on-site measurements, household surveys, policy analyses and joint problem solving into identifying new land management options. A modelling approach which uses assessment indicators to define impacts of land management was chosen. The model also identifies trade-offs and synergies in different land management options. During this phase, demonstration trials were established at the plot level. In the last phase, the focus has shifted more and more towards implementation activities, for example policy briefings and training for farmers, village heads and administrative staff. Discussions with key actors amongst the practitioners, who can influence implementation, have started as early as possible. This follows the assumption that the more "realistic" the concepts are, and the better they are communicated to, and discussed with, the stakeholders, the greater the likelihood of implementation.

Apart from the scientists, three key stakeholder groups have been identified, namely rubber farmers (often the village heads), regional decision-makers (prefecture administration and rubber companies), and provincial politicians. The main initiative, as well as the process of moderation, came from the group of scientists. Practitioners participate regularly at workshops and meetings. They express their interests regarding future rubber cultivation, and the information they would like to get from the researchers, and how this should be communicated.

Experience shows that communication processes initiated by research play a key role and must be managed carefully. It is clear that significant resources and long-term commitment are needed, and that even "long" research projects of five years are not sufficient to reach full implementation or create impact.

Location: Yunnan, Xishuangbanna
Approach area: 19,700 km^2
Type of approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: A_CHN054en
Related technology: T_CHN056en (Mitigating negative impacts of rubber monoculture by integrating native trees with new weed management)
Compiled by: Thomas Aenis and Jue Wang, Humboldt-Universität zu Berlin, Extension and Communication Group, www.agrarberatung.hu-berlin.de, thomas.aenis@agrar.hu-berlin-de, jue.wang.1@agrar.hu-berlin-de
Date: 27th January 2016, updated June 2016

Problem, objectives and constraints

Problems:

In Xishuangbanna, Southwest China, monocultivation of rubber (*Hevea brasiliensis*) has enhanced farmers' livelihoods fundamentally - but also caused severe environmental and societal problems. In order to sustain land use, a high standard of interdisciplinary integration as well as transdisciplinary communication and cooperation between researchers, practitioners and policy/administration is required this is to (at least partially) implement solutions to the complex problems related to sustainable land management. The more heterogeneous the actors are, the more challenging is the process of effective communication. However, commonly, neither procedures nor channels are established for such communication.

Aims / Objectives:

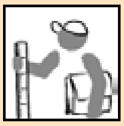
The holistic approach towards research-practice-integration combines scientific analyses with a range of activities to enhance interaction and collaborative learning amongst practitioners and researchers. This fosters the development of sustainable land use practices – amongst others the related technology: "Mitigating negative impacts of rubber monocultures by integrating native trees and changed weed management – and policies" (with an emphasis on sustainable rubber cultivation), and a start to implementation of project research results.

Constraints addressed

	Constraints	Treatments
Workload	Practitioners in the SURUMER research project are not convinced by the importance and necessity of stakeholder dialogue.	Internal communication during plenary workshops, etc., to achieve agreement on stakeholder involvement and the role and responsibility of scientist in the stakeholder dialogue.
Social / cultural / religious	Local stakeholders are not well aware of the linkage between rubber monoculture and environmental degradation, and that the high profitability of rubber encourages this monoculture.	Through a small exhibition, focus group discussions, workshops and meetings, the research results and scientific findings have been presented to local stakeholders in order to raise awareness.
Institutional	Under the framework conditions of rural China with its strong social hierarchy, decision-making is top-down. Farmers are very dependent on the government. Participation in regional land use planning is not an established concept, and local people are hesitant to actively demand change. They seldom try out innovations such as intercropping or reduced use of agro-chemicals by themselves: rather they accept government-led innovations - if they are subsidised.	Changing farmers' perceptions of technologies through ongoing communication: bilateral communication, focus group discussions and workshops. Awareness building about the problem and general approach: Training on "responsible use of agro-chemicals". Demonstration plots could serve for monitoring of effects and as the location for future field schools.
Legal / land use and / water rights	Farmers might not want to invest in trees because of limited duration of the land rights (maximum 50 to 70 years of usufruct right only), and rented land (usually 10-year contracts).	No (ongoing discussion external to the project).

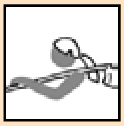
Participation and decision making

Stakeholders / target groups



SLM specialists / agricultural advisors

politicians / decision makers



land users, groups

Approach costs met by:

– international: concept and implementation, facilitation; etc (Federal Ministry of Education and Research, BMBF)	90%
– local government (prefecture)	10%
Total	**100%**

Annual budget for SLM component: US$10,000-100,000

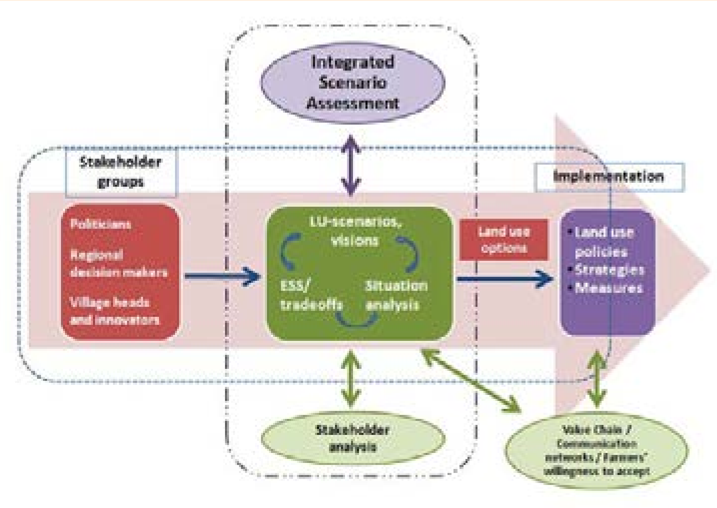
Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology: Mainly by SLM specialists with consultation of land users
Approach designed by: International specialists
Implementing bodies: International (SURUMER project), local government (prefecture), regional administration, research institutes, rubber processing companies, and local community/ land users (village heads, farmers)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	None	n/a
Planning	Passive	Approach and Technology planned by German and Chinese scientists with local partners: most important the Naban River Watershed National Nature Reserve Bureau. Mainly by informal communication, meetings and planning workshops.
Implementation	Interactive	German and Chinese researchers cooperated in organizing stakeholder workshops and presenting preliminary research results . Three groups of stakeholders (politicians, regional decision makers, and village heads) were actively involved through interviews, focus groups, etc. Nature reserve administration operates demonstration plots, supervised by German scientists, who are also responsible for performance monitoring.
Monitoring/evaluation	Passive	Stakeholders who participated in the dialogue gave feedback and evaluated the approach. The approach was also evaluated by an external team of experts.
Research	Passive	Land users were the main source of information for stakeholder analysis, economic studies, and a study on willingness to accept changes. Results of research were fed back into the approach. For example presenting the concept and preliminary results of integrating native trees in stakeholder workshops further management options such as reduced use of agro-chemicals were discussed.

Differences between participation of men and women: No

Involvement of disadvantaged groups: Yes, moderate. Poor farmers involved during baseline survey, using semi-structured interviews.



Organogram: The discourses with the three stakeholder groups are focused on a joint situation analysis, discussion on the future of rubber, and discussion about ecosystem services and functions under different scenarios. Land use options are developed jointly and consequences concerning local policies, cultivation measures and market strategies are then discussed. Stakeholder discourses are linked with integrated scenario assessment and modelling by an inter-disciplinary group of scientists. (source: Thomas Aenis)

Technical support

Training / awareness raising: Training provided for land users, field staff/ agricultural advisors. Training comprised courses, demonstration plots, public meetings, site visits/ farmer to farmer exchange. Training focused (a) on agro-chemicals: problems, awareness, treatment; (b) on water protection: awareness, treatment; (c) on intercropping: demonstration
Advisory service: Yes, the nature reserve administration organized the training and operates the demonstration field.
Research: Yes, strong support by research. Topics covered include sociology, economics / marketing. Mostly on-station and on-farm research.
1. Research on transdisciplinary communication and stakeholder participation.
2. Research on rubber value chain and alternatives

External material support / subsidies

None

Monitoring and evaluation

Monitored aspects	Methods and indicators
Management of Approach	Regular observations by project staff
No. of land users involved	Regular observations by project staff

Changes as result of monitoring and evaluation: There were few changes in the approach. Regional stakeholder workshops were planned twice per year. However, through the stakeholder evaluation process it was learned that once a year would be better.. There was a shift from open discussion to a more structured presentation of results and discussion of management options.

Impacts of the Approach

Improved sustainable land management: Yes, moderate.
1. Through research-practice interaction, the land users get to know that there are linkages between large-scale rubber monoculture and environmental degradation.
2. The stakeholders get to know each other, expand their communication networks, which will help when they are making land-use and land management decisions.
3. The stakeholders get access to latest scientific results on sustainable land management from the SURUMER project, which provides them new options for sustainable land management.

Adoption by other land users / projects: Yes, few. The Green Rubber project which is led by the local research institute, has included stakeholder dialogue as an element.

Improved livelihoods / human well-being: No, not yet. The effects of improved livelihoods can only be seen in the long term.

Improved situation of disadvantaged groups: No. The effect can only be seen in the long term.

Poverty alleviation: No. Once again, the effect will only be seen in the long term.

Training, advisory service and research:

- Training effectiveness
  Land users: fair
  Immediate feedback was received on the use of agro-chemicals.
- Research contributing to the approach's effectiveness
  Research on stakeholder participation is the basis for the approach design. As stakeholder involvement is an iterative process, the approach was adjusted according to experience in its application, to make sure that the approach is updated according to the current situation and stakeholders' needs. Very positive feedback from the local partner (nature reserve administration)

Land/water use rights: Hinder: moderately in the implementation of the approach. Water management and land use management always involves different stakeholders along the river or in the area, with complex ownership or user rights. Under the framework condition in rural China, it is difficult to involve different stakeholders and set-up a stakeholder dialogue, especially with those who have conflicting interests. The approach did reduce the land/water use rights problem (low). The approach has little impact on land users' behaviour.

Long-term impact of subsidies: No subsidies given

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Environmental consciousness, health; to protect the water quality and quantity, and biodiversity. Rules and regulations (fines) / enforcement: There are regional regulations towards more 'green' rubber cultivation supporting well-being and livelihoods.

Sustainability of activities: It is uncertain whether the land users will be able to sustain the approach activities without support. In the SURUMER project, the stakeholder dialogue is designed and facilitated by project staff. Although our local partner and local stakeholders give very positive feedback regarding this process, it is hard to say that they will continue such an approach without external support.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Stakeholders are widely targeted from the decision makers to the end users e.g. farmers → Transfer the network from the project to the stakeholders themselves, build interlinks among stakeholders.	Process is slower than expected → Clear consensus has to be reached beforehand.
Efficient communication via various channels, which together produce holistic and valuable knowledge about problems and possible solutions → Choose suitable communication channels according to the specific situation and stakeholder group	Cost in terms of various resources: labour, time, money → Choose the most suitable way of participation based on efficiency.
A workshop series is a suitable structure for in-depth discussion with key regional decision-makers on focus topics → The local partner is interested in the way that such participation processes take place, and has expressed willingness to transfer such an approach into collaboration with other partners.	Scientists' interests are much more in research than in interactive activities → Internal discussion is needed, it deepens understanding about the whole project.
Various participation methods together enrich the information and provide the possibility of cross-checking → Documentation of how the methods have been applied under which situation, for further application.	It is not possible to discuss the scientific scenarios with local stakeholders due to the insurmountable gulf between modellers' academic jargon and everyday language → Adjustment of scenario discussion, discuss further expectations with stakeholders instead, which could be translated into trade-offs and integrated into modelling.
Through wide participation, it is more likely that decisions are fair → Take all possible stakeholders into consideration; attention needs to be paid to those groups with power, and those without.	Because of social hierarchy, and the top-down decision-making system, participation is not a well-established concept, and local people are hesitant to take part in it → Information flow increased from researchers to stakeholders, understanding and trust built through showing research results with the issues they are most concerned with, such as water quality and quantity, soil degradation, value chains and market studies. They are interested in the topic and gradually began to actively participate.
Social learning with changing attitudes and behaviour towards participation in the long term → Continued communication and exchange.	

Key reference(s): Aenis, T., Wang J. (2016) From information giving to mutual scenario definition: Stakeholder participation towards Sustainable Rubber Cultivation in Xishuangbanna, Southwest China. In: Aenis, T. et al. (eds.) (2016) Farming Systems Facing Global Challenges: Capacities and Strategies (Volume 1) – Proceedings of the 11th European IFSA Symposium, 1-4 April 2014 in Berlin, Germany. • Wang J. et al. (2016) Triangulation in participation: Approaches for science-practice interaction in land-use decision making in rural China. (submitted to Land Use Policy). • Hofmann-Souki et al. (2016) Participatory assessment of value chains for diversifying small-scale farms – developing a tool for practitioner-led analysis and innovation. 12th IFSA Europe Symposium "Social and technological transformation of farming systems: Diverging and converging pathways". July 12th - 15th, 2016. Harper Adams University, Shropshire, UK. Online:
Contact person(s): Thomas Aenis, Humboldt-Universität zu Berlin, Extension and Communication Group, D-10099 Belin, www.agrarberatung.hu-berlin.de

left: Building area St. Leonhardsgarten situated at the former tram depot Altewiekring in Brunswiek (Johanna Fick)
right: Former tram depot Altewiekring in Brunswieck (Stadtarchiv Braunschweig)

High-quality inner urban development

Germany - Qualitätsvolle Innenentwicklung (German)

A scenario simulation of land use change where high-quality inner urban development is promoted, including the rehabilitation of brownfields, reuse of vacant lots, use of gaps between buildings and the improvement of existing structures.

The best means of reducing land loss by settlement and infrastructure development is through fulfilling inner urban development potential. This "compact settlement development" makes the most efficient use of space. Simultaneously it contributes to the reduction of greenhouse gas emissions by the maintenance of farmland or forest areas on the outskirts of urban areas. One example is the rehabilitation and utilization of "brownfields", including previous industrial areas. Another example is redevelopment of transportation infrastructure within settlements or on the urban fringe. However, the revitalization and utilization of brownfields is often expensive. Other aspects of inner urban development are the reuse of vacant lots, the use of spaces between buildings and the improvement of existing building structures by adding extra floors.

Through these developments, the rate of daily land consumption by settlement and transportation can be reduced. In Germany, such land loss reached 73 ha/day in 2010. According to a survey commissioned by the Federal Office for Building and Regional Planning, 20% of existing brownfields and vacant lots can be brought into use in the short term and another 50% of the total in the long term: 30% cannot be developed for various reasons including disputed tenure. The ambitious aim of the sustainability strategy of the German federal government is to reduce today's daily land consumption for settlement and transport from the current 73 ha/day to 30 ha/day by 2020. However this appears unrealistic: nevertheless with high-quality inner urban development technology, this could be achieved by 2030. If the technology is planned and implemented through scenario simulation of sectoral land use changes in Germany (agriculture, forest and settlements), then calculations show that the daily land loss by settlement and transport could be reduced from 45 ha/day in a "business as usual" scenario (with some improvements assumed) to 30 ha/per day in 2030 by using high-quality inner urban development measures.

During re-densification of urban areas sufficient green spaces must be protected to address climate change considerations such as higher temperatures and more runoff. High urban densities lead to an increase in the "heat island effect" (a combination of extensive urban/ suburban landscapes with reduced air circulation, little cloud cover and long periods of high temperature). Thus, the rehabilitation of brownfields has to go along with the transformation of impervious surfaces into permeable ones, and planning of corridors for air exchange by "green and blue climate corridors" (public parks, ponds and rivers). There are several initiatives to establish high quality inner urban development in Germany. These include: 1) "Inner before external" urban development within the Federal Building Law; 2) Many communities operating a brownfields and vacant lots cadastre; 3) General management of urban areas. Nevertheless, the reuse of inner city brownfields often requires considerable and costly remediation of contaminated sites. Due to the ownership issues of vacant lots, many are not easily accessible through municipalities, and this complicates their development. In other cases, available construction areas or buildings are not appropriate to the needs of investors.

Location: Germany, North Rhine-Westphalia
Region: Rheinisch-Bergischer Kreis and Rhein-Sieg-Kreis
Technology area: 1590 km^2
Conservation measure: management
Stage of intervention: mitigation / reduction of land degradation
Origin: developed externally / introduced through project, recent (<10 years ago)
Land use type: settlements, infrastructure networks (before), recreation areas (after)
Climate: humid, temperate
WOCAT database reference: T_GER006en
Related approach: A_GER003en (Open dialogue platform on sustainable land management)
Compiled by: Johanna Fick, Thünen Institute, Brunswieck, Germany
Date: 28th July 2015, updated June 2016

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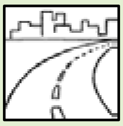
Climate Change — Land Use Strategies

Classification

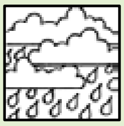
Land use problems: Land use for settlement and transport leads to imperviousness, and a reduction of high quality agricultural areas. Sealed surfaces increase runoff during heavy rain events, and high building densities promote the development of urban heat islands (expert's point of view). In fast-growing regions, high demand requires the supply of additional land for construction (land user's point of view).

Land use



settlements, infrastructure networks (before), recreation areas (after)

Climate

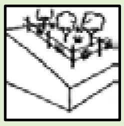


humid

Degradation

physical soil deterioration: loss of bio-productive function

Conservation measure



management: change of management

Stage of intervention

- □ Prevention
- ■ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative
- □ Experiments / research
- ■ Externally introduced (<10 years ago)

Level of technical knowledge

- □ Agricultural advisor
- □ Land user
- ■ Scientific staff

Main causes of land degradation:
Direct causes - Human induced: urbanization and infrastructure development

Main technical functions:
- spatial arrangement and diversification of land use
- reduces the loss of agricultural land and forests

Secondary technical functions:
none

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- ■ 1000-1500
- ■ 750-1000
- ■ 500-750
- ■ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- ■ 1000-1500
- ■ 500-1000
- □ 100-500
- □ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- ■ hill slopes
- □ footslopes
- ■ valley floors

Slope (%)

not relevant

Soil depth (cm)

not relevant

Growing season(s): not applicable
Soil texture: not applicable
Soil fertility: not applicable
Topsoil organic matter: not applicable
Soil drainage/infiltration: not applicable

Soil water storage capacity: not applicable
Ground water table: not applicable
Availability of surface water: not applicable
Water quality: not applicable
Biodiversity: not applicable

Tolerant of climatic extremes: seasonal rainfall decrease, decreasing length of growing period
Sensitive to climatic extremes: temperature increase, heavy rainfall events (intensities and amount), these increase surface runoff during heavy rainfall events
If sensitive, what modifications were made / are possible: more intensive use of urban area through inner urban development leads also to an increase of impermeable areas. These can be addressed by urban blue and green corridors of parks and water bodies.

Human Environment

Land user: employee (company, government)
Population density: 200-500 persons/km^2
Annual population growth: < 0.5%
Land ownership: state, company, individual, not titled
Land use rights: communal (organised), individual

Importance of off-farm income: not applicable
Access to service and infrastructure: high
Types of other land: settlement / urban, infrastructure network (roads, railways, pipe lines, power lines), urban green areas, recreation, brownfields

Technical drawing

Green and blue structure like parks, trees, alleys (green) and water areas like rivers, canals, ponds and lakes (blue) are relevant issues especially with respect to the climate adaptation.
(Photo by Johanna Fick)

Implementation activities, inputs and costs

Establishment activities

1. Data collection
2. Implementation into the model and model calibration
3. Model runs
4. Evaluation
5. Scenario development

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
refer to remarks		
TOTAL		

Maintenance/recurrent activities

not applicable

Remarks:
Measures can be very different in terms of inputs and costs, and depend on the specific situation eg contaminated area of a former petrol station can have very high rehabilitation costs due to the need to detoxify the soil before new use. However other measures cost (effectively) no money at all eg legislation governing the reduction of the distance permitted between two new buildings by the local authorities.

Assessment

Impacts of the Technology	
Production and socio-economic benefits	**Production and socio-economic disadvantages**
+ return on sales after revitalisation of brownfields + compact settlement structures reduce cost for public transport and public infrastructure	
Socio-cultural benefits	**Socio-cultural disadvantages**
Ecological benefits	**Ecological disadvantages**
+ increased biodiversity + increased carbon sequestration	
Off-site benefits	**Off-site disadvantages**
++ compact settlement structure. Shorter trajectories for infrastructure (e.g. water/sewage pipeline, public transport)	
Contribution to human well-being/livelihoods	
++	

Benefits/costs according to land user	Benefits compared with costs	short-term:	long-term:
	Establishment	not specified	not specified
	Maintenance/recurrent	not specified	not specified

Acceptance/adoption:
There is no trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Scenario simulations help to identify hot spots and can indicate regions where inner urban development should be promoted by public institutions → Inner urban development is profitable if pressure on land is high, but needs to be also promoted in regions with lower population pressure to protect soils, nature and climate.	Nationwide simulation cannot indicate specific local sites where inner urban development should be pushed → The technology has showed the potential for Germany as a whole, but implementation depends on local authorities.
Inner urban development can have positive impacts on climate adaptation → To reach positive impacts on these climate issues it is necessary to establish "green and blue climate corridors" (e.g. networks of urban green areas and water bodies established or enhanced during re-vitalization of brownfields).	
Inner urban development can increase the attractiveness of towns (greater inner city mobility; more compact towns) → The technology improves inner-urban area development. For improvements to existing settlement areas, additional building activities (e.g. making buildings taller; concentrating housing) are possible. Side effects are a very concentrated settlement structure but with the advantage of reducing the sprawling out of settlements into agricultural land or wooded areas (i.e. outer development) and this saves GHG emissions and other ecosystem services ESS.	

Key reference(s): www.cc-landstrad.de, www.bbsr.bund.de

Contact person(s): Jana Hoymann, Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR), Deichmanns Aue 31-37, 53179 Bonn, NRW Germany, e-mail: jana.hoymann@bbr.bund.de

left: Extensive pastoral farming with cattle. (Photo: Norbert Röder)
right: Canary grass on re-wetted fens and half bogs harvested with adapted piste caterpillar. (Photo: Wendelin Wichtmann)

Adapted management of organic soils

Germany

Re-wetting of organic soils followed by adapted management - suitable for wet conditions like extensive grazing land or paludiculture.

In peat lands, formed over centuries, reducing the ground water level leads to mineralization: this results in greenhouse gas (GHG) emissions and leaching of dissolved organic nutrients into adjacent water bodies. Furthermore, drainage leads to the destruction of highly specialized ecosystems. Re-wetting, by removing of drainage systems (etc.), means the restoration of a higher ground water level which can reduce GHG emissions in the long term. Re-wetting to a water-level of 10 cm below the soil surface is ideal for reducing GHG emissions and preventing peat mineralization. One prerequisite for re-wetting is that soil degradation and peat mineralization are not too advanced. An adequate water supply must be available. Re-wetting also affects adjacent areas so possible impacts such as flooding of settlements and infrastructure must be considered.

Land uses suitable for the soil conditions after re-wetting are extensive grazing, or paludiculture. Paludiculture is the cultivation of wet organic soils by preserving or renewing peat by planting and harvesting specific trees (e.g. alder), reeds and sedges. On fens, alder trees (for wood /biomass production) or plant species grown for their products (e.g. for thatch) or bioenergy, including the common reed, reed canary grass or cat's-tail, can be cultivated. On peat bogs sphagnum farming as a peat substitute in horticulture, or as a medicinal plant, is possible. The first harvest of the common reed can take place four years post-establishment; thereafter annually. Alternatively, extensive livestock grazing with water buffalo or suitable breeds of cattle like Galloway or Heck has potential for re-wetted land. Year-round grazing is possible with a carrying capacity of up to 0.7 livestock units/ha.

Apart from avoiding huge amounts of GHG emissions and bringing land into alternative production, further aims of re-wetting and adapting land use are:

- soil protection (soil structure, water content, peat protection);
- water protection (water quality, buffering / filtering water);
- protection of the landscape's water regime and material balance (solute transport);
- biodiversity protection (retaining a sensitive ecosystem with specialized/ threatened species); and
- flood protection (organic soils can quickly absorb large amount of water).

There are many advantages for the environment while still creating a (modest) income for land users. Unlike most other bioenergy production chains (e.g. maize, rapeseed) which do not have these environmental co-benefits, paludiculture with the common reed can become a sustainable production system.

The Altmark region is located on the North German Plain. The region is predominantly characterized by agriculture but has many forests too. Because of the high proportion of grassland, cattle are important. The use of biomass for bioenergy was increasing and many biogas plants were established in the last few years. Fens are mostly located in Altmark-County Salzwedel. Here, the average population density (42.7 inhabitants km^2) is relatively low in the German context and the annual precipitation of 466mm is also below the overall German average.

Location: Germany, Saxony-Anhalt
Region: Altmarkkreis Salzwedel and district Stendal (total area of region: 4744 km²)
Technology area: ~ 288 km^2
Conservation measure: vegetative, structural, management
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago); nature protection, 10-50 years ago
Land use type: cropland: annual cropping (before and current), grazing land: extensive grazing land (after)
Climate: humid, temperate
WOCAT database reference: T_GER007en
Related approach: A_GER003en (Open dialogue platform on sustainable land management)
Compiled by: Johanna Fick, Thünen Institute
Date: 29th July 2015, updated June 2016

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Climate Change – Land Use Strategies

Classification

Land use problems: Drainage causes mineralization, sagging and reduction of organic matter of organic soils as well as high GHG emissions, disturbed water regimes, destruction of valuable ecosystems and loss of ecosystem services (expert's point of view). Long term use of drained organic soils leads to soil degradation and lower productivity. Thus, more fertilizer is needed. Due to sagging of organic soils, ditches and drainages need to be renewed every 10-15 years (land user's point of view).

Land use

cropland: annual cropping (before and current), grazing land: extensive grazing land (after)

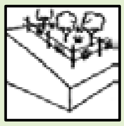
Climate

humid

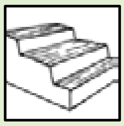
Degradation

physical soil deterioration: compaction, subsidence of organic soils, settling of soil, loss of bio-productive function

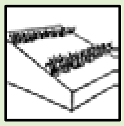
Conservation measure



change of land use type and management / intensity level, layout according to natural and human environment



structural: removal of drainage system, dykes etc. allowing rise in groundwater level



vegetative: grasses and perennial herbaceous plants (paludiculture)

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research: recent (<10 years ago)
Externally introduced
Other: nature protection: 10-50 years ago

Level of technical knowledge

Agricultural advisor
Land user
planners

Main causes of land degradation:
Direct causes - Human induced: soil management, disturbance of water cycle (infiltration / runoff)

Main technical functions:
- increase in organic matter
- increase / maintain water stored in soil
- increase of groundwater level / recharge of groundwater
- improvement of water quality, buffering / filtering water

Secondary technical functions:

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 234 days (spring-autumn)
Soil texture: not applicable
Soil fertility: low, very low
Topsoil organic matter: high (>3%)
Soil drainage/infiltration: water logged if re-wetted, good if intensively drained

Soil water storage capacity: very high
Ground water table: on surface
Availability of surface water: excess (eg flooding)
Water quality: for agricultural use only
Biodiversity: high post-treatment

Tolerant of climatic gradual change and extremes: seasonal rainfall increase, heavy rainfall events (intensities and amount), floods, decreasing length of growing period
Sensitive to climatic gradual change and extremes: temperature increase, seasonal rainfall decrease, droughts / dry spells
If sensitive, what modifications were made / are possible: none

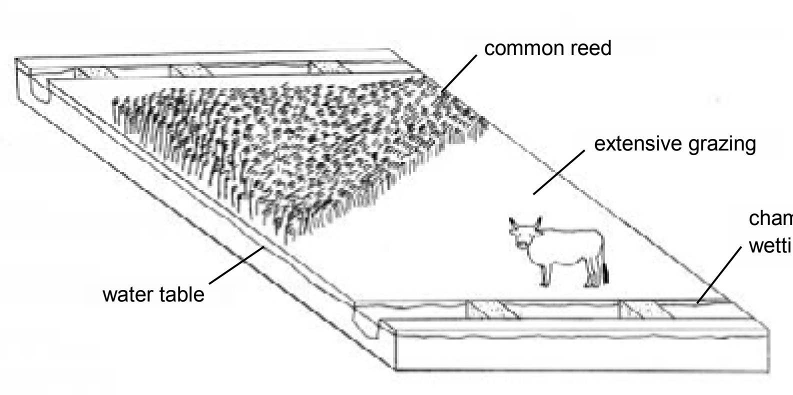
Human Environment

Cropland per household (ha)

Not relevant

Land user: groups / community, men and women
Population density: 10-50 persons/km^2
Annual population growth: negative
Land ownership: state, communal / village, NGO
Land use rights: individual
Water use rights: individual (Land owners can re-wet their land and manage it suitably for wet conditions afterwards. The State or an NGO, for example, can buy land and re-wet it; normally followed by nature protection. This technology cannot be carried out by a single land user. It has major impacts off-site and affects, normally, more than one farmer.)
Relative level of wealth: not applicable

Importance of off-farm income: not applicable
Access to service and infrastructure: not relevant
Market orientation: commercial / market
Mechanization: mechanised
Livestock grazing on cropland: not relevant



Technical drawing

Re-wetting of a fen with adapted agricultural land use afterwards: extensive grazing with cattle and paludiculture in Common Reed production, (Sarah Baum).

Implementation activities, inputs and costs

Establishment activities

1. For fen re-wetting, removal of drainage systems like ditches, pumping stations, dykes or drainages is necessary. Extent depends strongly on local site conditions. (Examples taken from Landesumweltamt Brandenburg (2014).
2. Extensive grassland: if the field is not already used as grassland but as cropland: grassland sowing
3. Extensive grassland: natural spread: no input required
4. Paludiculture: planting of common reed
5. Make-ready and setup costs eg engineering costs

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user*
Labour	300.00	
Equipment		
– machine use	400.00	
Agricultural		
– seedlings	2500.00	
Other		
– removal of drainage	200.00	
– ditch filling	100.00	
– make-ready and setup costs (per unit)	2500.00	
TOTAL	**6000.00**	100%

Maintenance/recurrent activities

1. Water level management: weir control ~once a week: requirements depend closely on local conditions. Control is also necessary when weirs are used to manage water level.
2. Extensive grassland: mowing
3. Extensive grassland: grazing with water buffalo, adapted cattle (e.g. Heck and Galloway breeds)
4. Paludiculture (common reed): harvesting
5. Management

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user*
Labour	250.00	
Equipment		
– machine use	600.00	
Other		
– management (per unit)	150.00	
TOTAL	**1000.00**	100%

*Changes with available amount of subsidies and depends on political preferences
Remarks: Only rough estimates on costs and income can be given due to the very new and innovative technology. The technology is still in the introductory phase at present.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+	reduced expenses on agricultural inputs
+	decreased workload

Production and socio-economic disadvantages

− − −	reduced crop production
− − −	reduced fodder production
− − −	reduced fodder quality
− − −	reduced animal production
− − −	increased risk of crop failure
− − −	increased demand for irrigation water
− − −	decreased farm income
− − −	loss of land

Ecological benefits

+ + +	reduced emission of carbon and greenhouse gases
+ + +	reduced soil loss
+ + +	reduced soil compaction
+ + +	high value for nature conservation/relevant species
+ +	increased water quantity
+ +	increased water quality
+ +	increased soil moisture
+ +	reduced surface runoff

Ecological benefits continued

+ +	recharge of groundwater table / aquifer
+ +	improved soil cover
+ +	increased nutrient cycling recharge
+ +	increased soil organic matter / below ground C
+ +	increased animal diversity
+ +	increased plant diversity
+ +	reduced invasive alien species
+ +	increased / maintained habitat diversity

Off-site benefits

+ +	reduced downstream flooding
+ +	increased stream flow in dry season
+ +	reduced groundwater river pollution
+ +	improved buffering / filtering capacity

Off-site disadvantages

− −	increased damage on neighbours fields

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very negative	negative
Maintenance/recurrent	very negative	negative

Depends strongly on subsidies and other incentive mechanisms as well as opportunity costs (regionally different). Furthermore, if re-wetting is not financed by the land user, the economic benefit is greater but less than before re-wetting.

Acceptance/adoption:
100% of land user families have implemented the technology with external material support. 0% of land user families have implemented the technology voluntary. There is no trend towards (growing) spontaneous adoption of the technology. There is no increasing trend to adopt the technology as it is not economically attractive to farmers. But for environment groups (NGOs), without an economical stake, this measure can be interesting as a pilot technology.

Concluding statements

Strengths and → how to sustain/improve

By re-wetting organic soil huge amounts of GHG emissions can be avoided on a relatively small area → Financial incentives for farmers are needed e.g. based on GHG-mitigation potential. Alternatively, areas can be bought by NGOs or government for re-wetting and nature protection

Paludiculture on re-wetted soils allows an alternative agricultural land use → Financial incentives (e.g. subsidies) for farmers are needed

Extensive grassland cultivation on re-wetted soils allows adapted land use – for grazing/mowing → Financial incentives (e.g. subsidies) for farmers are needed

The use of fertilizer and manure inputs leads to pollution of water bodies. The water quality will be enhanced by less fertilizer/manure input through this technology compared to intensive agriculture

Due to the technology, higher water retention, flood prevention and biodiversity can increase compared to use of drained organic soils.

Weaknesses and → how to overcome

High opportunity cost for land users: income from intensive cropland on drained soils is higher than income from re-wetted soils with extensive land use → The technology could be economically attractive if farmers get financial incentives for applying it (re-wetting and adapted extensive usage). It would become even more attractive if no incentives were paid for eg maize production on drained organic soils (those incentives are actually paid if the maize is used for bioenergy production).

On re-wetted soil land use options are very restricted due to wet soil conditions → Financial incentives for farmers are needed.

Key reference(s): Bonn A, et al. (2014) Klimaschutz durch Wiedervernässung von kohlenstoffreichen Böden. In: Naturkapital und Klimapolitik-Synergien und Konflikte. Naturkapital Deutschland TEEB DE Report. Technische Universität Berlin Helmholtz-Zentrum für Umweltforschung-UFZ, Berlin, Leipzig • Wichtmann W, Wichmann S (2011) Environmental, Social and Economic Aspects of a Sustainable Biomass Production. Journal of Sustainable Energy & Environment, Special Issue (2011):77-81

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left: Grassland can be used for making hay. (Photo: Norbert Röder)
right: Species-rich grassland. (Photo: Norbert Röder)

Grassland preservation

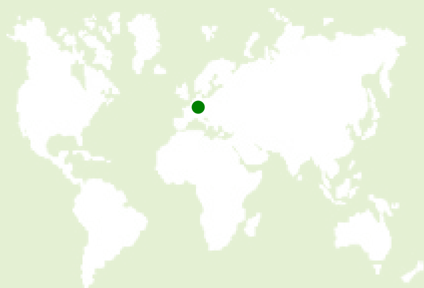
Germany

Grassland preservation by the avoidance of ploughing and conversion into cropland

Increasing demand for food, feed and bioenergy drives an extra requirement for cropland. This leads to conversion of grassland to cropland, and an intensification of the grassland that remains. Carbon stocks in grassland soils are higher for than for cropland, and within grasslands, stocks are substantially greater for old, humus-rich and boggy sites (e.g. fens or peatbogs) than for young grassland on mineral soils (Schuler et al. 2014). These differences are due to soil structure and the build-up of soil organic matter (SOM). By converting grassland to cropland, enhanced mineralization of SOM leads to high emissions of the greenhouse gas carbon dioxide (CO_2). Conversely, if cropland is converted to grassland a long-term carbon sink is established. On mineral soils the conversion of cropland to grassland can compensate the GHG emissions caused by the reverse procedure - but only in the medium to long-term (20-50 years). On organic soils this compensation is nearly impossible. On such organic soils the greenhouse gas (GHG) emissions caused by the conversion of grassland to cropland are more than 12.5 times higher per area unit compared to mineral soils (Baum, unpublished data based on data from the Federal Environment Agency UBA, 2014)). Avoiding the conversion of grassland into cropland avoids, on average, 10 t CO_2-eq $ha^{-1}yr^{-1}$ over a ten-year time period (Osterburg et al. 2009).

The aim of grassland preservation is to avoid/reduce GHG emissions and maintain and develop a carbon sink. Furthermore, grassland habitats have higher biodiversity than croplands and are, in general, less intensively managed. Thus, inputs of fertilizers and pesticides are lower, which is beneficial for water quality regardless of how intensively the grassland is managed. Unlike cropland, grassland is not ploughed or harrowed annually, resulting in better soil protection and a lower risk of erosion; the latter because of the year-round vegetation cover.

During a research project, the interdependencies between climate change and land use were analysed, and different strategies for sustainable land use management in Germany were modelled. Relevant land use measures which can contribute to the reduction of GHG emissions were evaluated with respect to climate mitigation, bioenergy by biomass, environmental and biodiversity protection (www.cc-landstrad.de). Grassland preservation is one land use practice which showed multiple advantages compared to cropland (after conversion from pasture): these were higher carbon sequestration and lower GHG emissions, better soil protection against erosion, and improved water storage capacity. The disadvantages and thus trade-off of grassland preservation are foregoing production of high-yielding cash crops, higher labour demand per hectare, and lower agricultural income. However, given the importance of preserving carbon stocks accumulated under grassland, the existing pastures should be retained wherever possible. The preservation of grassland is recommended everywhere, but especially for areas with organic soils/peaty soils - as high GHG emissions are the consequence otherwise.



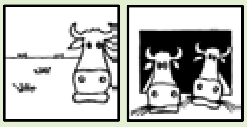
Location: Germany
Region: nationwide
Technology area: 375,000 km^2
Conservation measure: management
Stage of intervention: prevention of land degradation
Origin: developed externally / introduced through project, 10-50 years ago
Land use type: grazing land: extensive grazing land, intensive grazing/ fodder production
Climate: humid, temperate
WOCAT database reference: T_GER008en
Related approach: A_GER003en (Open dialogue platform on sustainable land management)
Compiled by: Johanna Fick, Thünen Institute, johanna.fick@thuenen.de
Date: 29th July 2015, updated June 2016

CC-LandStraD
Climate Change — Land Use Strategies

Classification

Land use problems: Increasing demand for cropland area, and higher income options by cultivating cropland rather than grassland, thus loss of GHGs through conversion (expert's point of view). Increasing demand for cropland area. Grassland conversion into cropland might increase the farmer’s income if the soil is suitable for cropping (land user's point of view).

Land use

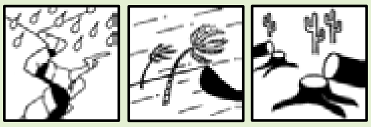


extensive grazing land — intensive grazing land / fodder production

Climate

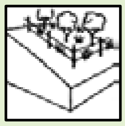
humid

Degradation



soil erosion by water: loss of topsoil — soil erosion by wind: loss of topsoil — biological: reduction of vegetation cover, loss of habitats, quality and species composition / diversity decline, loss of soil life

Conservation measure



management: management / intensity level

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research
Externally introduced: 10-15 years ago

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes: Human induced: soil management, crop management (annual, perennial, tree/shrub). Indirect causes: increasing demand for land

Main technical functions:
- improvement of ground cover
- stabilization of soil (e.g. by tree roots against landslides)
- increase in organic matter

Secondary technical functions:
- improvement of water quality, buffering / filtering water
- promotion of vegetation species and varieties (quality, e.g. palatable fodder)

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 150-270 days
Soil texture: not relevant
Soil fertility: not relevant
Topsoil organic matter: not applicable
Soil drainage/infiltration: not applicable

Soil water storage capacity: high compared to arable land
Ground water table: not relevant
Availability of surface water: not applicable
Water quality: for agricultural use only
Biodiversity: high

Tolerant of climatic gradual change and extremes: Temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells, decreasing length of growing period.
Sensitive to climatic extremes: no

Human Environment

Agricultural land per farming household (ha)

- □ <0.5
- □ 0.5-1
- □ 1-2
- □ 2-5
- ■ 5-15
- ■ 15-50
- □ 50-100
- □ 100-500
- □ 500-1,000
- □ 1,000-10,000
- □ >10,000

Land user: Individual / household, average land users, men and women
Population density: 200-500 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, titled
Land use rights: individual, titled
Water use rights: not relevant
Relative level of wealth: not applicable

Importance of off-farm income: not relevant
Access to services and infrastructure: not applicable
Market orientation: commercial / market, biodiversity conservation
Mechanization: good
Livestock grazing on agricultural land: 50-100 LU /km^2

Technical drawing

Extensive suckler cow husbandry (Norbert Röder)

Implementation activities, inputs and costs

Establishment activities

Not relevant for preservation of grassland

Maintenance/recurrent activities

The costs depend on the intensity of the management, the more intensive the use the higher the cost (e.g. reseeding etc.)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour for reseeding	135.00	100%
Equipment		
– machine use (seeders)	100.00	100%
Agricultural		
– seeds	100.00	100%
TOTAL	**335.00**	**100%**

Remarks: There are no direct costs if grassland is not converted but managed as before. However, there might be opportunity costs forgone: If a farmer converts his/her grassland to cropland and cultivates arable crops he/she might have a higher profit than he/she would have from grassland cultivation.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
	−− reduced crop production −− decreased farm income −− increased labour constraints − decreased drinking water availability / quality − reduced product diversification
Socio-cultural benefits	**Socio-cultural disadvantages**
Ecological benefits	**Ecological disadvantages**
++ reduced surface runoff ++ improved soil cover ++ increased nutrient cycling recharge ++ reduced emission of carbon and greenhouse gases ++ reduced soil loss + reduced hazard towards adverse events + increased soil organic matter / below ground C + reduced soil crusting / sealing + increased / maintained habitat diversity	
Off-site benefits	**Off-site disadvantages**
Contribution to human well-being/livelihoods	

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	negative
Maintenance/recurrent	negative	very negative

Main costs are opportunity costs of arable land use, they occur yearly.

Acceptance/adoption:
There is strong trend towards (growing) “spontaneous” adoption of the grassland preservation. Within the reformed Common Agricultural Policy of the EU grassland protection has been enhanced since 2015. In Germany, the conversion of grassland is subject to approval, and in general only permitted if a similar area of grassland is established in the same region to compensate for the loss.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
By avoiding conversion of grassland to cropland huge amounts of GHG emissions can be avoided. Further advantages are a lower risk of soil erosion, possible flood prevention, lower levels of fertilizers and pesticides leaching into runoff waters, and higher biodiversity conservation → Grassland preservation is enhanced by legal restrictions. Financial incentives for land users make grassland preservation more attractive from an economical point of view.	The income from grassland might – if location factors like soil, water availability are suitable – be lower than it would be for cropland. Thus, there can be high opportunity costs of preserving grassland → Grassland preservation can be enhanced by legal restrictions. Financial incentives for land users make grassland preservation more attractive from an economical point of view.
Conservation/restoration of regional typically landscapes → Grassland preservation is enhanced by legal restrictions. Financial incentives for land users make grassland preservation more attractive from an economical point of view.	

Key reference(s): Schuler J et al. (2014) Instrumente zur Stärkung von Synergien zwischen Natur- und Klimaschutz im Bereich Landbewirtschaftung. BfN-Skripten, pp. 187. Bonn, Bad Godesberg • Osterburg B et al. (2009) Erfassung, Bewertung und Minderung von Treibhausgasemissionen des deutschen Agrar- und Ernährungssektors. Studie im Auftrag des Bundesministeriums für Ernährung, Landwirtschaft und Verbraucherschutz. Arbeitsberichte aus der vTI-Agrarökonomie 2009/03, Braunschweig, Hamburg, Trenthorst • UBA (2014) http://www.umweltbundesamt.de/publikationen/schwerpunkte-2014.

Contact person(s): Sarah Baum, Thünen Institute of Rural Studies, Bundesallee 50, D-38116 Braunschweig, Lower Saxony, Germany, sarah.baum@thuenen.de

left: Cross-sectoral results of a workshop with different stakeholders on sustainable land use in Germany. (Photo: Annett Steinführer)
right: Discussion at the final stakeholder workshop of the German CC-LandStraD research project. (Photo: Helge Meyer-Borstel)

Open dialogue platform on sustainable land management

Germany

Establishing a dialogue platform on sustainable land management which is open to all stakeholders

The cross-sectoral stakeholder discussion platform on SLM aims to involve all relevant stakeholders in a specific SLM topic, or within a particular region in a dialogue process leading to better understanding and to a sustainable solution where there are multifunctional claims on land. The platform operates in Germany.

Examples of possible topics are to work out, together, the main land use conflicts in a region (e.g. reduced land for agriculture because of increased settlement pressures) and then to jointly develop sustainable solutions for the land use conflicts addressed. The platform was established by a non-governmental group within a transdisciplinary research project (CC-LandStraD) financed by the Federal Ministry of Education and Research (BMBF) in Germany. The transdisciplinary research approach is carried out in cooperation with regional authorities.

The platform provides a forum to discuss specific topics cross-sectorally (for example, agriculture, forestry, settlement and transportation, and nature conservation) and for multi-stakeholders (for example land users, advisors, specialists, planners, and decision makers). To establish this platform, a neutral setting and external moderation is helpful. Methods which can be used at the platform include separate sectoral and cross-sectoral workshops, excursions, information events and newsletters. Furthermore, there are simulations of different scenarios on current land use and on land use development and distribution, and at the same time there is cross-sectorial and transdisciplinary learning. This platform is not a single event, but an on-going process. Access barriers, for example an entrance fee, should not exist.

To initiate a platform, the most relevant aspects of a region/community and all related stakeholders have to be established through a stakeholder analysis. Interviews and surveys are employed to indicate who the relevant stakeholders are. During interviews the potential stakeholders are asked who they work with regarding land use. Further stages then focus on the most relevant aspects. These may be current land use conflicts like losses of agricultural land because of settlement and transportation infrastructure. Alternatively they can be conflicts regarding production of goods either for food, feed or energy purposes, or disputes concerning intensive or extensive agriculture, with the consequent implications on nature and environment conservation. Depending on which conflict is addressed, the relevant stakeholder and the process which is needed (e.g. sectoral talks, cross-sectoral talks, focus groups) can be identified. To identify the most relevant land use conflicts stakeholder are asked to rank the most relevant land use conflicts that affect them.

Each stakeholder is welcomed and has the opportunity to state his/her opinion in an open-result discussion. The cross-sectoral learning process is an important aspect of this approach. In the case presented case there is interaction between stakeholders from agriculture, forestry and settlement/transport as well as nature conservation, regional and environmental planning and governmental institutions. The stakeholders were asked for the main land use conflicts in their work, relevant measures to resolve the situation, and their design, then discussed the scenario assumption, and selected results and possible implications.

Location: Germany, Saxony-Anhalt, Altmarkkreis Salzwedel and district Stendal (total area of region: 4744 km²)
Approach area: nationwide
Type of approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: GER003en
Related technology: T_GER007en (Adapted management of organic soils), T_GER008en (Grassland preservation), T_GER006en (High-quality inner urban development)
Compiled by: Johanna Fick, Thünen Institute of Rural Studies, Bundesallee 50, D-38116 Braunschweig, Germany
Date: 04 August 2015, updated June 2016

Problem, objectives and constraints

Problems:

There are different and competing demands on land which can conflict with the conventional uses for agriculture and forestry. These include biomass for energy, new settlements and transportation infrastructure. Space is also needed for tourism and leisure facilities; and also for measures of environmental protection. All of these can have an impact on the area available for, and the management of, farmland and forests. And there are competing economic interests in land management. As land is a limited resource, problems between different stakeholders are inevitable and becoming more frequent.

Aims / Objectives:

A cross-sectoral stakeholder discussion platform on SLM aims at involving all relevant stakeholders around a specific SLM topic, or within a particular region in a dialogue process leading to better understanding and improved, sustainable, solutions. In a "business as usual" situation, generally no cross sectoral talks or interaction take place. With such a platform however, more knowledge and direct talks between stakeholders from different sectors provide the opportunity for solutions.

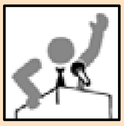
Constraints addressed

	Constraints	Treatments
Workload	To implement and run a dialogue platform it takes time and professional skills and resources (e.g. high motivation and high frustration tolerance, moderation and motivation methods, knowledge about group dynamics).	Be aware of this before the dialogue platform is set-up (such a process is not a one-off short-term, activity: it's better thought of as medium-long term process).
Social / cultural / religious	Stakeholders have different backgrounds, understanding and interests. Sometimes the relevant stakeholders don't know each other.	A neutral setting is required, so that no stakeholder has an advantage; external moderation, which is accepted by all involved stakeholders, is needed; also professional input by experts (e.g. from research institutions) so that a joint learning process starts. Here it is essential to provide a good atmosphere and a common understanding of the key questions.
Other	1. Stakeholders have different levels of knowledge and professionality 2. Previous conflicts (some known; some hidden) and other areas of controversy sometimes come to light during discussions.	1. It is necessary to make information accessible by moderation and to create common understanding (e.g. sometimes the same term exists in agriculture and forestry but has a different meaning). 2. Be sensitive to nonverbal communication or conflict topics and be prepared to deal with such issues even if not communicated verbally.
Financial	Different stakeholders have different resources to contribute to this platform (e.g., time, finance, knowledge, as well as practical aspects like office equipment - beamers, microphones etc.).	Try to keep the barriers as low as possible and equal for each and every stakeholder (e.g. no entrance fee, public invitations in advance, central meeting location, meeting at a suitable time for the stakeholders).

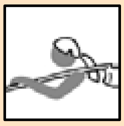
Participation and decision making

Stakeholders / target groups

planners



politicians / decision makers



land users, individual, groups

Approach costs met by:

– Federal government	95%
– Local government (district, county, municipality, village, etc.)	5%
Total	**100%**

Annual budget for SLM component: US$ < 2,000

Decisions on choice of the Technology: Options and possible measures are discussed in a multi-stakeholder dialogue process.
Decisions on method of implementing the Technology: No decisions have been made yet.
Approach designed by: National specialists
Implementing bodies: This approach was initiated by a non-governmental group of researchers in cooperation with regional authorities. But this approach is not related to one body. Either national non-governmental organisations, government, private sector, local government, local community, or a group of land users can initiate the approach.

Stakeholders involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	scientists working with transdisciplinary processes
Planning	Interactive	scientists on transdisciplinary processes and disciplinary scientists on SLM
Implementation	Passive / indirect	all involved stakeholders mentioned above; scientists = interactive
Monitoring/evaluation	Passive / indirect	all involved stakeholders mentioned above, scientists = interactive
Research	Interactive	all involved stakeholders mentioned above and all scientists

Differences between participation of men and women: No difference

Involvement of disadvantaged groups: Yes, little. Participating groups with fewer financial resources received travel grants

Organogram:
time sheet stakeholder participation on national level.
The 'sub-project' started in the first year with an overview workshop on current and future land use and climate change, followed by face-to-face interviews. The second year focused on the process to identify the most relevant measures for climate mitigation of each sector (agriculture, forestry, settlement and transportation, and nature conservation). The last three years were used to discuss preliminary results and to evaluate the results from the stakeholder perspectives. (Meike Hellmich, Annett Steinführer)

Technical support

Training / awareness raising: Awareness raising activities for land users, field staff, agricultural advisor and relevant stakeholders and involved people took place. The activities focused on each level/stage (measures, scenarios, results and implication) to provide knowledge to and with all participants in order to focus on the meeting's objectives and to raise awareness (why are we doing this? why is it important to be here? why should we talk about this topic?).

Advisory service: The extension system is quite adequate to ensure continuation of activities. The approach raised awareness and brought people together who normally don't discuss topics with each other.

Research: Research was very important to this approach. Topics covered include sociology, economics / marketing, ecology. Simulation of land use development in Germany was undertaken, including simulation of agricultural economics, forest economics and simulation of settlement and transport areas development, of GHG emissions of land use, and a population survey on perceptions of landscapes

External material support / subsidies

Contribution per area (state/private sector): Not relevant
Labour: Not relevant
Input:

- openness to share knowledge,
- scientific results to produce a common understanding
- facilities to hold workshops or other events.

Credit: Credit was not available

Support to local institutions: This method can support local/regional institutions via the input (mentioned above) and mutual discussions of regional associations and groups. However, certain groups may mutually exclude each other.

Monitoring and evaluation

Monitored aspects	Methods and indicators
socio-cultural	Observations by project staff: interviews by scientists at the end of the project regarding cross-sectoral and transdisciplinary approach

Changes as result of monitoring and evaluation: There were no changes in the approach.

Impacts of the Approach

Improved sustainable land management: Yes, moderate; the complex topic of land use and climate change (with a focus on climate change mitigation) was analysed and presented to the involved stakeholders. The interaction during cross-sectoral workshops gave a more detailed picture of SLM compared to workshops with a sectoral focus. The better knowledge base helps to improve SLM.
Adoption by other land users / projects: Yes, some; the approach is used in regional development processes sometimes.
Improved livelihoods / human well-being: Yes, little; the awareness of intensive land use in Germany and in our focus regions was raised, especially regarding the interaction between agricultural land use and (for example) water quality because of intensive agriculture including the application of fertilizers, pesticides or herbicides. Often these chemical inputs cannot be absorbed by plants or soil so the unused resources concentrate in groundwater which thus needs to be purified before drinking. Land use improvements can be achieved by agreeing the division between settlement, transport and land for agricultural production - and also for sustainable land use to reduce GHG emissions in agriculture and forestry.
Improved situation of disadvantaged groups: Not in the focus
Poverty alleviation: No
Training, advisory service and research:

- Research contributing to the approach`s effectiveness:
  Moderately. The simulation results on the development of land use in Germany were a major input to the dialogue platform. Applies in this context, but research it is not necessarily required. It depends on the key questions which are supposed to be discussed in the dialogue platform. Research results might be a good base for the dialogue.

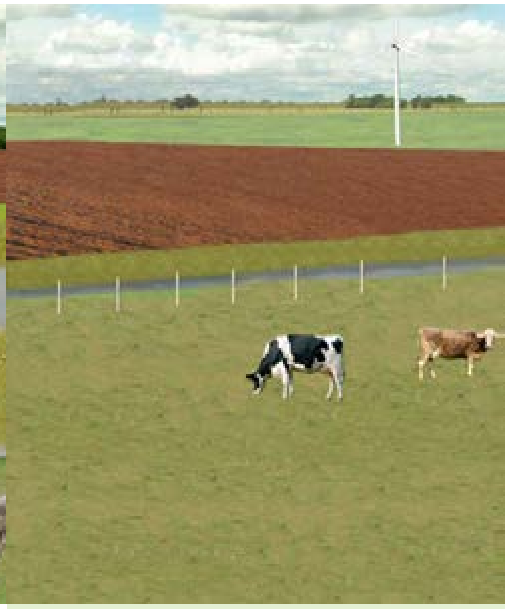
Land/water use rights: Help - moderately - in the implementation of the approach. The land ownership, land use rights/water rights are quite clear in Germany. So it is easy to identify the relevant stakeholders on SLM. But these are only a few target groups. There are much more which are relevant to get a good platform on SLM e.g. nature conservation groups, tourism associations.
Long-term impact of subsidies: not relevant

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Affiliation to movement / project / group /networks: in this approach all land using sectors were involved for the first time.
Sustainability of activities: Yes the approach activities can be sustained without support. This approach is suitable for different levels, for various topics with different combinations of stakeholders involved.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Added value e.g. research can be used to provide new input → clear announcement of added value for different target groups.	There should be added value for land users, and the added value should be addressed clearly → e.g. new information provided by researcher must be tailored to the different stakeholders.
All relevant stakeholders are involved → make sure that all relevant stakeholders are identified during the initial stakeholder analysis.	It takes time to produce the right working atmosphere and to reach a consensus → avoid short-term initiatives.
Cross-sectoral and sectoral meetings by turn, depending on specific aspects of the meeting → problem and solution oriented talks and meetings.	The moderation has to be accepted by all stakeholders
Neutral setting and external moderation	
New information and knowledge by researcher is shared → cooperation with research institution.	
New information, innovative methods and results, current political trends → presentation of new information has to be in language/ terminology suitable for the target groups.	

Key reference(s): Steinhäußer, R. et al. (2015) National and regional land-use conflicts in Germany from the perspective of stakeholders. Land Use Policy 49, 183-194. • Lange, A.; Siebert, R.; Barkmann, T. (2016) Incrementality and Regional Bridging: Instruments for Promoting Stakeholder Participation in Land Use Management in Northern Germany. In: Society & Natural Resources, Jul2016, Vol. 29 Issue 7, p868-879, 12p.
Contact person(s): Johanna Fick, Thünen Institute of Rural Studies, Bundesallee 50, D-38116 Braunschweig, Germany. johanna.fick@ti.bund.de



left: Water retention area close to the primary sea wall with the delineation of the retention area and the land use as developed in a participatory process with local experts (Photo: Research project 'COMTESS')
right: Detailed view within the water retention area with the delineation of the retention area and the land use as developed in a participatory process with local experts (Photo: Research project 'COMTESS')

Water retention polders to improve water management

Germany - Polder zum Wassermanagement entwickelt durch lokale Experten (Nordsee Region)

Water retaining polders to reduce flood risk due to heavy rainfall or runoff at high tide in embanked coastal lowlands. Delineation of the retention area and land use within the retention area was developed in a participatory process with local experts.

In the 19th and 20th century land was reclaimed from the sea to make use of the exposed fertile soils for agriculture through a process known as 'impoldering'. The reclaimed land is now characterized by intensive grazing and cropland. This is a region where agriculture is the most important form of land use. However, the land needs to be regularly drained. Given the expected increase in precipitation in winter due to climate change, the corresponding increase in freshwater discharge needs to be managed. Furthermore, the periods when natural discharge into the sea occurs are likely to decrease – because of rising sea levels also caused by climate change. Consequently, in winter and spring, greater quantities of freshwater will need to be pumped into the sea rather than discharged naturally at the low or 'ebb' tide. Specially embanked water retention polders will be required to temporarily impound water as part of a multifunctional approach to coastal zone management.

These retention polders could be a cost-effective alternative to expensive investments in extra pumping capacities to prevent submergence of low-lying cultivated areas. The primary aim is to restrict floods to the retention polders when the drainage network is overburdened and cannot deal with the predicted extra demands in the future. The high evapotranspiration from the open waterbody, and the reeds growing within, will also help with reducing the amount of water. During dry summers, the water in the retention polder could also be put to creative use as a source of irrigation. Another potential advantage is that subsurface saltwater intrusion in the region could be prevented by the freshwater-filled polders. During extreme storm surges and in the rare case of breaches in the sea wall, the retention polders would serve as an extra line of defence by holding seawater.

An embankment enclosing approx. 500 ha will be able to store up to 2,500,000 m³ of water. This will improve the drainage of an area of approx. 49,000 ha. The investment for building this water retention area is high – but for the reasons stated it serves a necessary purpose at a cost which is lower than the alternative – increased pumped drainage installations. Maintenance costs will be lower than the drainage alternative as only the integrity of the embankment needs to be monitored regularly. Currently, agricultural land use within the polders is adapted to higher water levels and occasional flooding. Within the embanked area there will be a change from the current use of mainly crop land to extensive grazing, open water and reed stands.

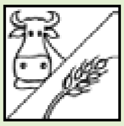
Some parts within the retention polder will be used for agricultural purposes, while the wetter parts will be set aside. In these latter sections, undisturbed natural regeneration will take place. A landscape comprising various different elements, without any extreme forms of intensive land use such as large areas of monocultures will be the result. Thus requirements for agricultural use and tourism will be addressed.

Location: Germany, Lower Saxony
Region: Landkreis Aurich
Technology area: 33.7 km^2
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: developed through experiments / research, 10-50 years ago; externally / introduced through project, 10-50 years ago
Land use type: agro-pastoralism (before), wastelands, swamps, recreation areas (after)
Climate: humid, temperate
WOCAT database reference: T_GER003en
Related approach: A_GER001en (Stakeholder participation in integrated assessment and planning of vulnerable coastal regions)
Compiled by: Martin Maier, University of Oldenburg, 26111 Oldenburg, Germany, martin.maier@uni-oldenburg.de
Date: 10th June 2015, updated June 2016

Classification

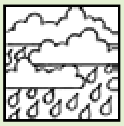
Land use problems: Flood events and droughts may substantially disrupt the current land use system in the future and lead to higher drainage costs and higher economic risks for agricultural production. This will reduce the ecological and economic viability of the current intensive and highly productive land use under a changing climate (expert's point of view). There is no awareness of risks due to climate change in the land users' point of view.

Land use



agro-pastoralism (before), wastelands, swamps, recreation areas (after), rainfed

Climate

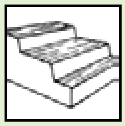


humid

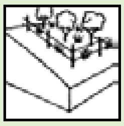
Degradation

water degradation: change in quantity of surface water

Conservation measure



structural: dams / pans: store excessive water



management: change of intensity level /change of land use type

Stage of intervention

- Prevention
- Mitigation / Reduction
- Rehabilitation

Origin

- Land user's initiative: recent (<10 years ago)
- Experiments / research: 10-50 years ago
- Externally introduced: 10-50 years ago

Level of technical knowledge

- Agricultural advisor
- Land user
- Water board

Main causes of land degradation:
Direct causes - Natural: change of seasonal rainfall, Heavy / extreme rainfall (intensity / amounts), floods.

Main technical functions:
- control of dispersed runoff: retain / trap
- control of concentrated runoff: retain / trap

Secondary technical functions:
- increase / maintain water stored in soil
- increase of groundwater level / recharge of groundwater
- spatial arrangement and diversification of land use

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Growing season(s): 240 days (March to October)
Soil texture: fine / heavy (clay)
Soil fertility: high
Topsoil organic matter: high (>3%)
Soil drainage/infiltration: medium

Soil water storage capacity: high
Ground water table: < 5 m
Availability of surface water: good
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells
Sensitive to climatic gradual change and extremes: sea level rise and more heavy rainfall events (intensities and amount)
If sensitive, what modifications were made / are possible: water retention polders to avoid inland flooding

Human Environment

Mixed per household (ha)

Size (ha)
<0.5
0.5-1
1-2
2-5
5-15
15-50
50-100
100-500
500-1,000
1,000-10,000
>10,000

Land user: employee (company, government), large scale land users, average land users, men and women
Population density: 50-100 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, not titled
Land use rights: individual
Relative level of wealth: average, which represents 50% of the land users; 50% of the total area is owned by average land users

Importance of off-farm income: 10-50% of all income: Many farmers do additional work in companies
Access to service and infrastructure: moderate: employment (e.g. off-farm), market; high: health, education, technical assistance, energy, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market

Technical drawing

The figure shows the study region, located on the North Sea coast. The whole area is protected by a sea wall (grey). Crop fields (yellow), grasslands (green) and the drainage system (light blue) characterize the region. In contrast to T_GER001en and T_GER002en small water bodies (blue) surrounded by reeds (brown) act as water retention polders. Agricultural land use in some retention areas is adapted to the ground water levels and flooding frequencies. This results in parts of the retention areas being taken out of agricultural production and undisturbed development of natural habitats occurring. In other parts of the retention areas extensive grazing or reed farming will be practiced. This leads to a mosaic of different land uses in the landscape. Retention areas of 500 ha are able to store up to 2,500,000 m³ water. The height of the dams depends on the elevation of the landscape but in general a height of less than 2 m is sufficient. (Udo Schotten).

Implementation activities, inputs and costs

Establishment activities

1. Building of dams

Establishment inputs and costs per retention area

Inputs	Costs (US$)	% met by land user
Labour	10’000’000.00	0%
Equipment and material		
– machine use	4’000’000.00	0%
– earth	112’000.00	0%
TOTAL	**14’112’000.00**	**0%**

Maintenance/recurrent activities

1. Control of dams
2. Maintenance of dams
3. Maintenance of drainage system

Maintenance/recurrent inputs and costs per km per year

Inputs	Costs (US$)	% met by land user
Labour	500.00	0%
Equipment and material		
– machine use	200.00	0%
– earth	100.00	0%
Maintenance per km ditch	2,270.70	0%
TOTAL	**3,070.70**	**0%**

Remarks:
The establishment costs are for a dam length of 30 km and the enclosed retention area of 3,000 ha. The establishment period will be half a year. The slope in the region determines the costs as the height of the embankments depend on this. Typical heights are from 1 m up to 2 m with a slope of 1:3. The length of the drainage network for the whole watershed (retention area and the surroundings) is 1,134 km. Maintenance costs of the drainage network are based on long term annual mean cost of 2,270.70 Euro per km including pumping costs. The maintenance cost for the whole retention area will amount to a total of US$ 2,576,200.00.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- ++ increased water availability
- ++ less intrusion by saline groundwater
- ++ reduced expenses on agricultural inputs
- ++ diversification of income sources (reed production, tourism, extensive grazing)

Production and socio-economic disadvantages

- − reduced fodder production
- − reduced fodder quality
- − decreased farm income

Socio-cultural benefits

- + increased recreational opportunities
- + improved conservation / erosion knowledge

Socio-cultural disadvantages

Ecological benefits

- + increased water quantity
- + increased animal diversity
- + increased plant diversity

Ecological benefits continued

- + increased / maintained habitat diversity
- + increased evapotranspiration

Off-site benefits

- ++ reduced downstream flooding
- ++ reduced damage on neighbours fields
- ++ reduced damage on public / private infrastructure
- ++ reduced excess water

Off-site benefits continued

- ++ reduced hazard towards adverse events
- + increased water availability
- + increased stream flow in dry season

Contribution to human well-being/livelihoods

- ++ 'Regional belonging' and 'feeling of safety' are measured. The amount of increase is modelled and will be added here.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	neutral / balanced
Maintenance/recurrent	slightly positive	very positive

The benefits will be visible in a longer timeframe. There will be benefits from the investments when considering sea level rise in the upcoming 100 years.

Acceptance/adoption: The SLM technology was developed together with regional experts. It seems that the ideas developed, are emerging more regularly in recent discussions and implementation is likely.

Concluding statements

Strengths and → how to sustain/improve

Prevention of flooding during heavy rainfall and possibility of irrigation during dry periods → The larger the retention areas, the more water can be stored.

Prevention of salt water intrusion → Fresh water in the retention areas prevents saline ground water from intrusion. Build polders in areas where saline ground water intrudes.

Endangered species might obtain new habitats in the retention area → Extensive land use can help to optimize the habitats for endangered species and increase attractiveness for tourism

Through investments in building retention polders the very expensive strengthening of the existing drainage system is no longer necessary → By increasing the attractiveness for tourism alternative benefits for land owner can be generated.

Multi-functional land use in the catchment and in the retention polders → Support farmers with land in the retention area (e.g. financially or with additional agricultural land outside the retention area). Support discussions between farmers' associations and nature conservation agencies

The retention area will supplement the drainage of the arable fields and pastures outside the retention area → Combine with other technical solutions for protection against flooding.

Weaknesses and → how to overcome

Loss of land for agricultural production → Create retention polders where the productivity is already low. Encourage alternative land use (for example reed production) in the retention polders.

High water levels (especially with changing levels) may generate high emissions of greenhouse gases → Groundwater levels should be kept stable and close to the soil surface.

Retention area is probably too small if pessimistic sea level rise predictions come true → Increase size of retention polders.

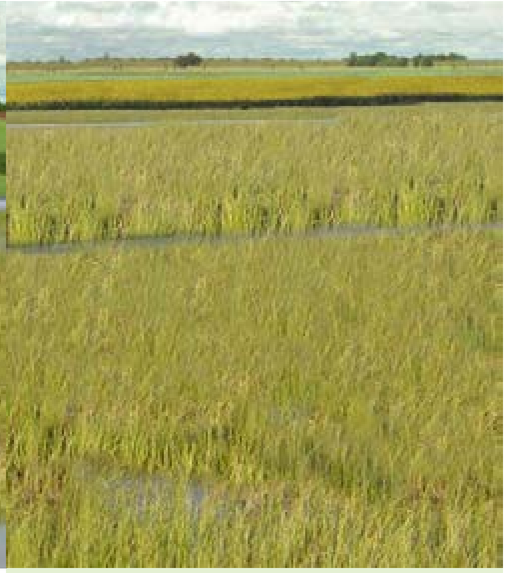
The retention polders will change the landscape and this may reduce the value of the region for tourism → Include tourist concerns within the retention area (accessibility, information, attractiveness)

Endangered species might lose habitats when establishing the retention polders → Do not build them where endangered species live

Loss of livelihoods → Retention polders should be planned for parts of the landscape without settlements

Key reference(s): http://www.comtess.uni-oldenburg.de/

Contact person(s): Martin Maier, University of Oldenburg, 26111 Oldenburg, Germany, martin.maier@uni-oldenburg.de • Michael Kleyer, University of Oldenburg, 26111 Oldenburg, Germany, michael.kleyer@uni-oldenburg.de



left: Water retention area without agricultural land use close to the primary sea wall (Photo: Research project 'COMTESS')
right: Detailed view within the water retention polder without agricultural land use (Photo: Research project 'COMTESS')

Water retention polders without agriculture to improve water management

Germany - Ungenutzter Polder zur Verbesserung des Wassermanagements (Nordsee Region)

Water retention polders to reduce flood risk due to heavy rainfall or runoff at high tide in coastal lowlands. The retention polders are used to accumulate organic material for climate change mitigation and enable development of undisturbed natural habitats, rather than for agriculture.

In the 19th and 20th century land was reclaimed from the sea to make use of the exposed fertile soils for agriculture through a process known as 'impoldering'. The reclaimed land is now characterized by intensive grazing and cropland. This is a region where agriculture is the most important form of land use. However, the land needs to be regularly drained. Given the expected increase in precipitation in winter due to climate change, the corresponding increase in freshwater discharge needs to be managed. Furthermore, the periods when natural discharge into the sea occurs are likely to decrease – because of rising sea levels also caused by climate change. Consequently, in winter and spring, greater quantities of freshwater will need to be pumped into the sea rather than discharged naturally at the low or 'ebb' tide. Specially embanked water retention polders will be required to temporarily impound water as part of a multifunctional approach to coastal zone management.

These retention polders could be a cost-effective alternative to expensive investments in extra pumping capacities to prevent submergence of low-lying cultivated areas. The primary aim is to restrict floods to the retention polders when the drainage network is overburdened and cannot deal with the predicted extra demands in the future. The high evapotranspiration from the open waterbody, and the reeds growing within, will also help with reducing the amount of water. During dry summers, the water in the retention polder could also be put to creative use as a source of irrigation. Another potential advantage is that subsurface saltwater intrusion in the region could be prevented by the freshwater-filled polders. During extreme storm surges and in the rare case of breaches in the sea wall, the retention polders would serve as an extra line of defence by holding seawater.

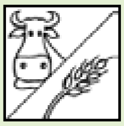
An embankment enclosing approx. 3,000 ha will be able to store up to 25,000,000 m³ water. This will improve the drainage of an area of approx. 49,000 ha. The investment for building this water retention area is high – but for the reasons stated it serves a necessary purpose at a cost which is lower than the alternative – increased pumped drainage installations. Maintenance costs will be lower than the drainage alternative as only the integrity of the embankment needs to be monitored regularly. However within the proposed retention polders – the areas enclosed by the embankment - no agricultural activity will take place. This will lead to a change from the current intensive grazing for dairy farming and cropland to non-agricultural use. And therefore a development towards swamps, reed stands and open waters will take place. It is expected that a development to undisturbed natural habitats will increase the number of endangered species. There will be an accumulation of organic material (and organic carbon) in the form of peat due to the wet conditions within the retention polders. Carbon will be sequestered by plant growth and thus reduce the amount of CO_2 in the atmosphere. The natural regeneration within the embanked areas will be attractive for tourism and recreation, which should provide an opportunity for additional income generation for the local population.

Location: Germany, Lower Saxony
Region: Landkreis Aurich
Technology area: 33.7 km^2
Conservation measure: structural
Stage of intervention: prevention of land degradation
Origin: developed through experiments / research, 10-50 years ago; externally / introduced through project, 10-50 years ago
Land use type: agro-pastoralism (before), wastelands, swamp, recreation areas (after)
Climate: humid, temperate
WOCAT database reference: T_GER002en
Related approach: A_GER001en (Stakeholder participation in integrated assessment and planning of vulnerable coastal regions)
Compiled by: Martin Maier, University of Oldenburg, 26111 Oldenburg, Germany, martin.maier@uni-oldenburg.de
Date: 9th June 2015, updated June 2016

Classification

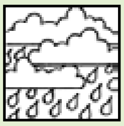
Land use problems: Flood events and droughts may substantially disrupt the current land use system in the future and lead to higher drainage costs and higher economic risks for agricultural production. This will reduce the ecological and economic viability of the current intensive and highly productive land use under a changing climate (expert's point of view). There is no awareness of risks due to climate change in the land users' point of view.

Land use



agro-pastoralism (before), wastelands, swamps, recreation areas (after), rainfed

Climate

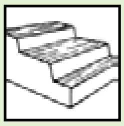


humid

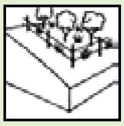
Degradation

water degradation: change in quantity of surface water

Conservation measure



structural: dams / pans: store excessive water



management: change of intensity level /change of land use type

Stage of intervention

- Prevention
- Mitigation / Reduction
- Rehabilitation

Origin

- Land user's initiative
- Experiments / research: 10-50 years ago
- Externally introduced: 10-50 years ago

Level of technical knowledge

- Agricultural advisor
- Land user
- Water board

Main causes of land degradation:
Direct causes - Natural: change of seasonal rainfall, Heavy / extreme rainfall (intensity / amounts), floods.

Main technical functions:
- control of dispersed runoff: retain / trap
- control of concentrated runoff: retain / trap

Secondary technical functions:
- increase / maintain water stored in soil
- increase of groundwater level / recharge of groundwater

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Growing season(s): 240 days (March to October)
Soil texture: fine / heavy (clay)
Soil fertility: high
Topsoil organic matter: high (>3%)
Soil drainage/infiltration: medium

Soil water storage capacity: high
Ground water table: < 5 m
Availability of surface water: good
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells
Sensitive to climatic gradual change and extremes: sea level rise and more heavy rainfall events (intensities and amount)
If sensitive, what modifications were made / are possible: water retention polders to avoid inland flooding. Climate mitigation due to CO_2 sequestration.

Human Environment

Mixed per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: employee (company, government), large scale land users, average land users, men and women
Population density: 50-100 persons/km^2
Annual population growth: < 0.5%
Land ownership: individual, not titled
Land use rights: individual
Relative level of wealth: average, which represents 50% of the land users; 50% of the total area is owned by average land users

Importance of off-farm income: 10-50% of all income: Many farmers do additional work in industry or servicing sector
Access to service and infrastructure: moderate: employment (e.g. off-farm), market; high: health, education, technical assistance, energy, roads & transport, drinking water and sanitation, financial services
Market orientation: commercial / market

Technical drawing

The figure shows the study region, located on the North Sea coast. The whole area is protected by a sea wall (grey). Crop fields (yellow), grasslands (green) and the drainage system (light blue) characterize the region. Large water bodies (blue) surrounded by reeds (brown) act as water retention polders. Vegetative regeneration, build-up of peat and re-establishment of natural habitats occurs within the retention polders. The land around the retention polders (the higher parts of the landscape) profits from the retention areas as the risk of flooding is reduced and can be used for cropland and intensive grazing. Depending on the size of the retention area a huge amount of excess water can be contained. Retention areas of 3,000 ha are able to store up to 25,000,000 m³ water. The height of the dams depends on the elevation of the landscape but in general a height of less than 2 m is sufficient. (Udo Schotten).

Implementation activities, inputs and costs

Establishment activities

1. Building of dams

Establishment inputs and costs per retention area

Inputs	Costs (US$)	% met by land user
Labour	21,000,000.00	0%
Equipment and material		
– machine use	9,000',00.00	0%
– earth	750,000.00	0%
TOTAL	**30,750,000.00**	**0%**

Maintenance/recurrent activities

1. Control of dams
2. Maintenance of dams
3. Maintenance of drainage system

Maintenance/recurrent inputs and costs per km per year

Inputs	Costs (US$)	% met by land user
Labour	800.00	0%
Equipment and material		
– machine use	300.00	0%
– earth	100.00	0%
Maintenance per km ditch	2,270.70	0%
TOTAL	**3,470.70**	**0%**

Remarks:
The establishment costs are based on a dam length of 30 km to enclose the retention area of 3 000. The establishment period will be half a year. The elevation in the region determines the costs as the height of the embankments depend on this. Typical heights are from 1 m up to 2 m with a slope of 1:3. The length of the drainage network for the whole watershed (retention area and the surroundings) is 1,074 km. Maintenance costs of drainage network are based on long term annual mean cost of Euro 2,270.70 per km including pumping costs. The maintenance cost for the whole retention area will amount to a total of US$ 2,441,200.00.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- +++ reduced expenses on agricultural inputs
- ++ less intrusion by saline groundwater

Production and socio-economic disadvantages

- −−− reduced crop production
- −−− reduced fodder production
- −−− decreased farm income

Socio-cultural benefits

- \+ increased recreational opportunities
- \+ improved conservation / erosion knowledge

Socio-cultural disadvantages

Ecological benefits

- ++ increased water quality
- ++ increased biomass above ground C
- ++ increased soil organic matter / below ground C
- ++ reduced salinity

Ecological benefits continued

- ++ increased evapotranspiration
- \+ increased animal diversity
- \+ increased plant diversity
- \+ increased beneficial species

Off-site benefits

- +++ reduced downstream flooding
- +++ reduced damage on neighbours fields
- +++ reduced damage on public / private infrastructure
- +++ reduced excess water
- +++ reduced hazard towards adverse events
- ++ increased water availability
- ++ increased stream flow in dry season

Off-site disadvantages

- − loss of area for agricultural production

Contribution to human well-being/livelihoods

\+ 'Regional belonging' and 'feeling of safety' are measured.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very negative	neutral / balanced
Maintenance/recurrent	neutral / balanced	positive

The benefits will be visible in the longer time frame. There will be benefits of the investments when considering sea level rise in the upcoming 100 years.

Acceptance/adoption: The technology is not yet implemented by land users. First it needs to be considered in spatial planning of the county and the federal state. Land users and local experts indicated, during participatory workshops, that there may be a chance of implementation.

Concluding statements

Strengths and → how to sustain/improve

Prevention of flooding during strong rainfalls and possibility to irrigate during dry periods → The larger the retention polders are the more water can be stored.

Prevention of salt water intrusion in the region. Fresh water in the retention areas prevent saline ground water from up dwelling → Build polders where saline ground water dwells up.

Endangered species might obtain new habitats in the retention area → Cessation of agricultural land use can help to improve the habitats for endangered species and increase attractiveness for tourism.

Through investments in building retention areas the very expensive strengthening of existing drainage structures is not necessary anymore → Alternative benefits for land owner can be generated e.g. increasing the attractiveness for tourism.

Protection of vulnerable landscape by establishing the retention polders in the lowest parts of the landscape that are already difficult to drain. The retention area will support the drainage of the arable fields and pastures outside the retention area → Combine with other technical solutions for protection against flooding (including strengthening of the ditch system and increasing pumping capacity).

Weaknesses and → how to overcome

Loss of land for agricultural production → Build-up retention polders in lowest parts, where the productivity is already poor.

For peat formation wet conditions are necessary, but under wet conditions highest methane emissions were measured. The emissions due to methane are therefore higher than the potential storage effects due to carbon sequestration → Ground water levels should be kept stable and close to the soil surface.

Retention polders in a region of high relevance for tourism. The retention area will change the landscape and this may reduce the value of the region for tourism → Include interests from tourism in the retention area (access, information, attractiveness).

Endangered species might lose habitats when establishing the retention polders → Do not build a retention area where endangered species live.

Loss of livelihoods → Retention areas should be planned for parts of the landscape without settlements.

Key reference(s): http://www.comtess.uni-oldenburg.de/

Contact person(s): Martin Maier, University of Oldenburg, 26111 Oldenburg, Germany, martin.maier@uni-oldenburg.de • Michael Kleyer, University of Oldenburg, 26111 Oldenburg, Germany, michael.kleyer@uni-oldenburg.de

left: Assessment of stakeholder preferences. The local and regional decision-makers ranked land use elements and ecosystem services according to their relevance for the case study region. (Photo: Leena Karrasch)
right: World Cafe for discussing land management option and possible future landscapes. (Photo: Elke Wegener)

Stakeholder participation in integrated assessment and planning of vulnerable coastal regions

Germany - Stakeholder Partizipation und integrative Entscheidungshilfen für gefährdete Küstenregionen (Deutsch)

Stakeholders have been involved in integrated assessment to develop action-oriented land use options addressing possible climate change adaptation measures as alternatives to traditional coastal protection strategies.

The SLM approach described here comprises knowledge transfer between the scientific community and practitioners through a "stakeholder-scientist partnership". The exchange of individual positions, interests and needs concerning spatial planning activities and sustainable land use management was very important. This was also true for the investigation of relationships and interactions between the different stakeholders. Furthermore, a stakeholder-based definition of land use elements and ecosystem services enabled the stakeholders to work with scientific concepts. Land use elements are delineated spatial areas related to one specific use of land, such as arable fields, infrastructure or aquatic areas. Ecosystem services, by definition the benefits people obtain from ecosystems, include provisioning, regulation, cultural and supporting services. The assessment of stakeholder preferences concerning each land use element and ecosystem service allowed an evaluation by scientists and researchers. All suggestions made by the stakeholders are included in the project results.

In total, there were 38 qualitative interviews carried out about the stakeholders opinion concerning sustainable and adaptive land use management (with one representative from each sector), 14 quantitative interviews to determine the relationship between land use elements and ecosystem services, several telephone and email conversations, 7 focus groups (interviews with more than one representative of each sector), and 4 regional forums (attended by representatives of all sectors). Each participatory process addressed a specific issue, such as determining preferences, relationships or scenario development. These plenaries provided a platform for stakeholder discussions, group assessments and consensus-building processes on the different issues. The focus groups were built to discuss sector-specific issues in greater depth and to support the joint decision-making process. All the results were triangulated and validated.

A heterogeneous expert group including all relevant actors (incl. land users) in the case study region was convened. Fourteen local and regional stakeholders acted as representatives of the various sectors: water management, nature conservation, agriculture, regional and local governmental bodies, and tourism. They covered all relevant fields and levels (from administrative to policy) of decision-making in the community of Krummhörn. The role of the researcher during the participatory governance process is characterised as the "knowledge-broker". The knowledge-broker acted at the interface between research and the stakeholders. The tasks were to provide the context (land use) and detailed information (ecosystem services) and determine decision-alternatives (land management scenarios) enabling and clarifying the freedom of choice. Additionally, the knowledge-broker translated research results to facilitate the dialogue between the different sectors and strengthen collaboration.

Location: Germany, Lower Saxony, County of Aurich, community of Krummhörn
Approach area: 160 km^2
Type of approach: project / programme based
Focus: mainly on other activities
WOCAT database reference: A_GER001en
Related technology: T_GER003en (Water retention polders to improve water management)
Compiled by: Martin Maier, University of Oldenburg, martin.maier@uni-oldenburg.de
Date: 10th March 2015, updated 2016

Problem, objectives and constraints

Problems:

Coastal zones with their natural and societal sub-systems are exposed to rapid changes and pressures on resources. Scarcity of space and impacts of climate change are dominant drivers of land use and adaptation management today. The population of vulnerable coastal regions has to deal with these complex problems, and to develop suitable options for land use and adaptation management considering socio-economic and environmental changes and their impacts on the land management, and vice-versa the impact of land management on the socio-economy and the environment. Future land use management needs to focus on the interactions of the entire human-nature system, aiming at more sustainable development while focusing on the benefits that ecosystems provide for people.

Aims / Objectives:

The aim of the approach is to foster a more sustainable and adaptive future land use management process by including social, ecological and economic impacts of possible developments in the decision-making processes.

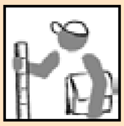
Constraints addressed

	Constraints	Treatments
Social / cultural / religious	The stakeholders are concerned that the land their ancestors reclaimed from the sea might be taken back again. Furthermore, the stakeholders feared that current flood protection structures would be endangered by new developments such as water retention areas.	Provide a platform for direct knowledge exchange between different stakeholders and scientists and joint development of land management options, ensuring active participation in transparent decision-making, and providing positive outcomes for all participants.
Institutional	Disagreement between different sectors.	Consensus finding through a participatory process.
Financial	The land used as a retention area is partially available for other land use. High costs for construction and development of retention area.	Explanation of benefits provided by nature (ecosystem services). Calculation of expected costs without changes in land management such as increased pumping costs.

Participation and decision making

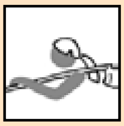
Stakeholders / target groups

planners



SLM specialists / agricultural advisors

politicians / decision makers



land users, groups

Approach costs met by:

– Government (Federal Ministry of Education and Research, BMBF)	100%
Total	**100%**

Annual budget for SLM component:
US$ 10,000-100,000

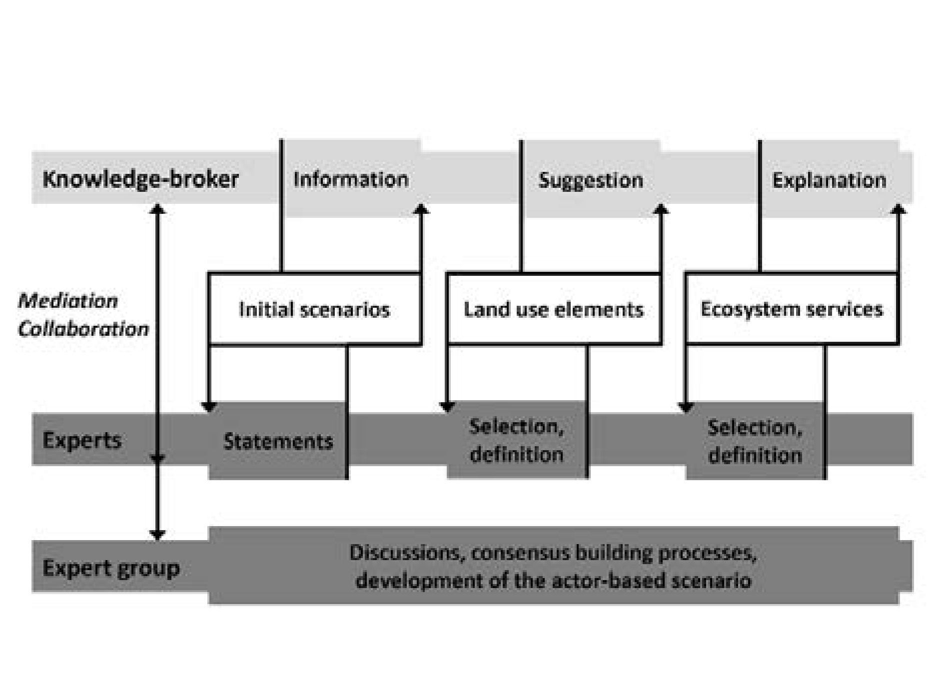
Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users.
Decisions on method of implementing the Technology: Mainly by land users supported by SLM specialists.
Approach designed by: Scientists
Implementing bodies: local government (district, county, municipality, village etc) (county of Aurich and community of Krummhörn), local community / land users (Waterboard and Dike authorities), private sector, national non-government, government.

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Interactive	Stakeholder analysis (snowball-principle) to include all interest groups.
Planning	Interactive	Local and regional decision-makers designed an actor-based scenario. They defined relevant land use elements and ecosystem services. The various stakeholders ranked the land use elements and ecosystem services according to their preferences. Furthermore, they determined the importance of each land use element for a certain ecosystem service.
Implementation	Interactive	The regional spatial planning authority implements the results from the approach.
Monitoring/evaluation	None	Not yet
Research	Passive	The stakeholders have been informed about the research results.

Differences between participation of men and women: Yes, great. Most decision makers are male

Involvement of disadvantaged groups: No
There has been no discrimination inside the communities up to now



Organogram: Description of the interactions between theknowledge-broker(scientist), individual experts (local and regional decision-makers) and the expert group. The initial scenarios prepared by researchers informed the experts about different land use options. The experts gave statements judging the initial scenarios. Based on this feedback the researcher suggested land use elements and explained ecosystem services which have been selected and defined by the experts.
This information was used by the expert group to discuss and develop the actor-based scenario. (Leena Karrasch)

Technical support

Training / awareness raising: Training provided for land users, field staff/agricultural advisors, decision makers. Training comprised courses, demonstration areas, public meetings, knowledge brokerage, site visits / farmer-to-farmer visits. Training focused on possible consequences of climate change
Advisory service: The extension system is adequate to ensure continuation of activities. They are aware of possible adaptation measures, based on scientific information and group consensus building.
Research: Strong research involvement. Topics covered include sociology, technology, economics / marketing, ecology. Mostly on-station and on-farm research. A transdisciplinary research project worked on providing information and collecting data concerning sociology, economics, ecology and technology. This information was used for the work with the stakeholders, to illustrate possible future scenarios and available land management options with their consequences. The results are shown in technology T_GER003en. Furthermore, these results were fed into models based on climate change and sea level rise scenarios. These models show the effects of the proposed land management on the ecosystem services provided in the region.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: None
Input: None
Credit: Credit was not available
Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
none	not applicable

Changes as result of monitoring and evaluation: There were no changes in the planning approach.

Impacts of the Approach

Improved sustainable land management: Yes, great. Awareness of challenges and understanding related to land use due to climate change was increased and support to design desired future land management was provided. Ideas for more sustainable land management have been implemented in the regional plan.
Adoption by other land users / projects: Yes, many; Regional plan (*'Regionales Raumordnungsprogramm'*) for the county of Aurich adopted the approach to tackle the impact of climate change.
Improved livelihoods / human well-being: No; It may improve livelihoods in future.
Improved situation of disadvantaged groups: No; It may improve the situation of socially and economically disadvantaged groups in future.
Poverty alleviation: No. Poverty is not the issue addressed by this approach.
Training, advisory service and research:

- Training effectiveness:
  Agricultural advisor / trainers, politicians / decision-makers, and users, SLM specialists, planners, nature conservationist, tourism administration, water managers: good
  A consensus-based decision making concerning future land use took place through collaboration and exchange of knowledge between the different sectors.
- Advisory service effectiveness:
  Technicians / conservation specialists, politicians / decision makers, planners, land users, tourism administration, water managers agricultural advisor: good
  Discussing a set of possible ecosystem services provided by land use elements enabled the different sectors to focus on a more ecosystem based management.
- Research contributing to the approach's effectiveness:
  Significantly. Input concerning the effects of climate change and the impacts of different land management systems helped stakeholders to imagine future conditions in the region and how to search for solutions.

Land/water use rights: No effect of land ownership or water rights on the approach.
Long-term impact of subsidies: None

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Environmental consciousness. Well-being and livelihoods improvement: including prevention of damage during extreme events. Increased profitability, improve cost-benefit ratio: indirect via adapted land use. Aesthetic. Production. Decision support: decision support for decision-makers.
Sustainability of activities: Yes, the land users can sustain the approach activities without support. It is very likely that the involved stakeholders will meet in future to continue the participatory process.

Strengths and → how to sustain/improve	**Weaknesses and → how to overcome**
Stakeholders provide input to planning processes, they are meaningful partners and provide local knowledge.	"Subjective" character of research → Trying to be as objective as possible.
Stakeholders help to identify risks, impacts and values.	Keep all stakeholders together → Give feedback; maintain an ongoing information process.
Stakeholder engagement as an important tool for implementing sustainable development and to link cross-sectoral interests.	It is difficult to include all different interests → Make the project interesting for everyone. Develop different options depending on the different interests and discuss the output (benefits and trade-offs).
Stakeholder collaboration promotes social learning processes, consideration of different world-views and cooperation and agreements.	The work with stakeholders is time intensive and challenging → Highlight the benefits and the time and commitment gained compared to approaches which do not include the stakeholders and what the consequences are.
Together with stakeholders of the region, concrete and action-oriented adaptive strategies will be developed.	Different world-views of different participants → Sufficient time for interaction and exchange. Be open-minded.
Active participation in transparent decision-making lead to positive outcomes for all participants. Participation is a positive and practical way to overcome controversial issues.	Time consuming meetings → Motivation, give feedback, ongoing information process (learning and knowledge exchange).
Research and scientists provide evidence and scenarios. They translated research results to facilitate the dialogue between the different sectors and strengthen the collaboration.	Scientific concepts are not easy understandable → Use of simple language and avoidance of scientific jargon.
The work on a common goal improves decision-making processes.	

Key reference(s): Leena Karrasch, Thomas Klenke, Johan Woltjer (2014) Linking the ecosystem services approach to social preferences and needs in integrated coastal land use management – A planning approach. In: Land Use Policy 38, 522-532; http://www.sciencedirect.com/science/article/pii/S0264837713002718
Contact person(s): Leena Karrasch, University of Oldenburg, D-26111, Oldenburg, Germany, leena.karrasch@uni-oldenburg.de

left: "Samata" propagation with cuttings (Photo: Herinavalona Rabemirindra)
right: Size and form of an ideal samata cutting (Photo: Herinavalona Rabemirindra)

Sustainable propagation of the fodder tree *Euphorbia stenoclada* ("samata")

Madagascar

Propagation of "samata" cuttings for long-term provision of supplementary livestock fodder to reduce the pressure on natural vegetation.

The succulent evergreen tree *Euphorbia stenoclada* ("samata") is the most important dry season fodder resource on the coastal plains grazing grounds in the Mahafaly Plateau region. To increase production, *samata* can be vegetatively propagated with cuttings raised in a nursery. The advantages are: (a) protection against livestock, (b) selection of the most appropriate planting stock to propagate and (c) easy watering. Cuttings should only be taken from mature trees 7-10 years old and 3-4 m high. The mother plants should be healthy, with few spines, and no previous cuttings taken. Cuttings are taken at the upper nodes of the branches, approximately 20-25 cm long and 0.5-1.5 cm diameter. Transport of the cuttings to the nursery should be carried out in the morning to avoid heat. For effective rooting, the cutting is planted 5 cm (1-2 nodes) into a humid substrate in a plastic pot or directly into the ground. Best results are achieved using white sea sand mixed with some organic material. Cuttings should be raised in a sunny location. During the first 15 days, the cuttings need to be watered once every morning. For the next 3-4 months, they need watering every second morning. 24 hours before transplantation from the nursery to the final destination, the cuttings should be abundantly watered. Rooted cuttings are transplanted into pits of 10 cm diameter and 15 cm depth, filled with the same substrate as used in the nursery. For 15 days, the transplants are watered on a daily basis, and afterwards every second day. After 30-45 days, the transplants are ready to survive without further care. If the planting location is open to roaming livestock, the cuttings need protection.

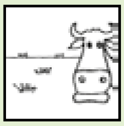
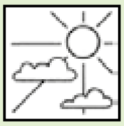
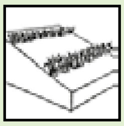
The *samata* tree naturally reproduces by seeds as well as by vegetative reproduction. However the German funded SULAMA research project has had most success with multiplication of the local variety with cuttings. This form of propagation is preferable as it is much faster and gives higher survival rates of the individuals: neither does it need much planting material, equipment or technical knowledge. Providing the villagers with the know-how, and assisting them to create local *samata*-nurseries, makes this technology promising. SuLaMa-WWF started this technique in April 2015, establishing 5 nurseries with 2,000 trees each (3 with village communities, 2 with local schools).

On the coastal plain of the Mahafaly plateau region, the climatic and edaphic conditions do not support livestock raising based mainly on grasses. For 6-7 months, the herders are dependent on supplementary fodder plants, especially *samata*. The tree is fed by cutting its branches and slicing them. However pressure on this resource has led to depletion of stocks around many villages: this results from increasing demand and reduced supply. Higher demand is the result of changed herd movements, especially a shorter transhumance period. Lower supply is attributed to decreased precipitation, overuse of trees leading to poor regeneration or even the death of trees, and reduced *samata* areas due to the expansion of private crop fields. The overuse of trees is triggered by the overall scarcity of this resource as well as an ongoing privatization of the historically common land resources.

Location: Atsimo-Andrefana, Toliara
Region: Toliara II, Beheloka
Technology area: 10-100 km^2
Conservation measure: vegetative
Stage of intervention: mitigation / reduction of land degradation, rehabilitation / reclamation of denuded land
Origin: developed through experiments / research, recent (<10 years ago); externally / introduced through project, recent (<10 years ago)
Land use type: grazing land: Extensive grazing land
Climate: semi-arid, tropics
WOCAT database reference: T_MAD002en
Related approach: None
Compiled by: Johanna Goetter, Brandenburg Technical University, Germany. goetter@b-tu.de
Date: 19th May 2015, updated June 2016

Classification

Land use problems: Climatic constraints (especially low and erratic precipitation), deforestation, forest degradation, soil degradation, overgrazing, loss of arable land, fragmentation, low availability of surface and (very saline) ground water, privatization of common pool resources (expert's point of view). Climatic constraints, loss of arable land, low availability of animal fodder, soil degradation, low availability of surface and (very saline) ground water (land user's point of view).

Land use	Climate	Degradation	Conservation measure
			
extensive grazing land rainfed	semi-arid	biological: reduction of vegetation cover, quantity / biomass decline	vegetative: tree and shrub cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative
Experiments / research: recent (<10 years ago)
Externally introduced: recent (<10 years ago)

Level of technical knowledge

Agricultural advisor
Land user
Scientific staff

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires), overgrazing
Direct causes - Natural: change of seasonal rainfall, droughts, cyclones
Indirect causes: population pressure, poverty / low education level, access to knowledge and support services

Main technical functions:
- increase of biomass (quantity)

Secondary technical functions:

Environment

Natural Environment

Average annual rainfall (mm)	Altitude (m a.s.l.)	Landform	Slope (%)
> 4000	> 4000	plateau / plains	flat
3000-4000	3000-4000	ridges	gentle
2000-3000	2500-3000	mountain slopes	moderate
1500-2000	2000-2500	hill slopes	rolling
1000-1500	1500-2000	footslopes	hilly
750-1000	1000-1500	valley floors	steep
500-750	500-1000		very steep
250-500	100-500		
< 250	<100		

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): June-September
Soil texture: coarse / light (sandy)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: very low
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: poor drinking water
Biodiversity: medium

Tolerant of climatic gradual change and extremes: seasonal rainfall increase
Sensitive to climatic gradual change and extremes: seasonal rainfall decrease, wind storms / dust storms, droughts / dry spells
If sensitive, what modifications were made / are possible: none

Human Environment

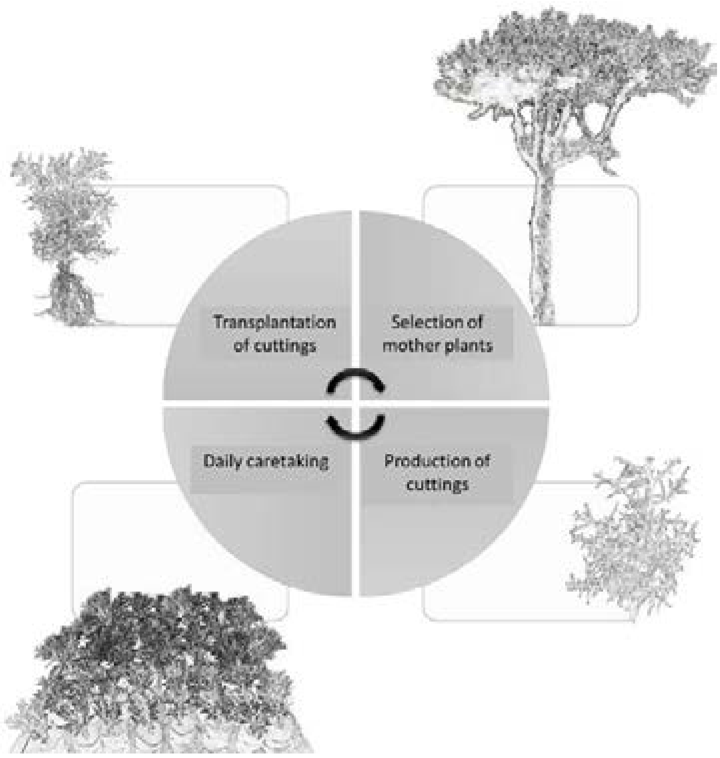
Agricultural fields per household (ha)

☐	<0.5
☐	0.5-1
■	1-2
☐	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
☐	1,000-10,000
☐	>10,000

Grazingland is communal

Land user: individual / household, small-scale land users, average land users, men and women
Population density: 10-50 persons/km^2
Annual population growth: 3% - 4%
Land ownership: state
Land use rights: individual, while land devoted to grazing is an open access common pool resource, but currently undergoing an unregulated privatization process.
Water use rights: open access (unorganised) (Land devoted by the communities for crop production belong to clans/lineages and their members; individual, untitled)
Relative level of wealth: poor, which represents 20% of the land users; very poor, which represents 70% of the land users

Importance of off-farm income: less than 10% of all income: business, trade, temporary labour migration, charcoal making
Access to service and infrastructure: low: health, education, technical assistance, employment (eg off-farm), energy, roads & transport, drinking water and sanitation, financial services; moderate: market
Market orientation: mixed (subsistence and commercial)
Livestock density: 1-10 LU /km^2



Technical drawing

Multiplication of *samata* trees through cuttings preferably in the cold season from June to August: (1) Selection of suitable mother plants: adult trees 7-10 years old, 3-4 m high, good phytosanitary condition, low in spines, without previous cuttings taken (2) Taking cuttings with a sharp knife at the upper nodes of the branches, approximately 20-25 cm long and 0.5-1.5 cm in diameter. To ensure the survival of the mother tree, at least 10 branches should remain uncut. Transportation of the cuttings to the nursery takes place preferably in the early morning to avoid heat. (3) Daily care of cuttings in nurseries till the roots are well-established. The cuttings are planted 5 cm deep (1-2 nodes) into a humid substrate in a plastic bag or pot, filled with a substrate of white ocean sand mixed with some organic material, for example dung (75% sand, 25% dung). During the first 15 days, the cuttings need to be watered once every morning. For the next 3-4 months, they need watering every second morning. Shade has to be avoided. (4) Transplanting cuttings: 24 hours before transplanting, the cuttings need to be abundantly watered. The rooted cuttings are transplanted into holes of 10 cm diameter and 15 cm depth, filled with the same substrate used in the nursery. For 15 days, the transplants are watered on a daily basis, and afterwards every second day. After 30-45 days, the transplants will be ready to survive without any further human attention. (RATOVONAMANA R. Yeddiya)

Implementation activities, inputs and costs

Establishment activities

1. Collection of cuttings from mother trees
2. Preparation of substrate and pots/plastic bags
3. Planting of cuttings in plastic pots/plastic bags
4. Watering of cuttings during the dry season
5. Fencing of final location for planting out (hedges of local material), if necessary
6. Transplantation of cuttings from plastic pots to final destination
7. Watering of small trees
8. Monitoring

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	415.00	100%
Equipment		
– tools	23.00	100%
Agriculture		
– earth and manure	7.50	100%
Other		
– transportation ox cart (hire)	9.30	100%
– plastic pots	93.00	100%
TOTAL	**547.80**	**100%**

Remarks:
The multiplication of *samata* trees comprise labour costs mainly. The time spent watering the cuttings is the most significant.
There are no maintenance costs, as after transplantation to final destination and watering for some month, there are no yearly recurring activities.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+++ increased fodder production	−− labour constraint
++ increased fodder quality	
+ increased animal production	
+ increased farm income	
+ decreased potential for conflicts on the use of wild *samata*	

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge	

Ecological benefits	Ecological disadvantages
++ increased beneficial species	
+ increased biomass above ground C	
+ increased shade for wild and domestic animals	
+ less pressure on / degradation of wild *samata*	

Off-site benefits	Off-site disadvantages

Contribution to human well-being/livelihoods

Still not, as technology still very new, knowledge transfer has just started very recently (April 2015).

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	very positive
Maintenance/recurrent	not specified	not specified

Acceptance/adoption: Unknown, as the knowledge transfer of the new technology has just started recently.

Concluding statements

Strengths and → how to sustain/improve

Land users are interested in applying this technology, as the *samata* tree is their main dry season fodder plant and overuse and scarcity today is severe → Providing land users with the technical knowledge and know how about *samata* propagation.

‘Artificial’ propagation of *samata* by vegetative multiplication (cuttings) does not require any special equipment or much specific knowledge.

Increasing the number of trees on the grazing land, and decreasing the pressure on trees enlarges the crown diameter of trees, thus providing additional shade for wild and domestic animals.

Weaknesses and → how to overcome

Land users are unaware that ‘artificial’ propagation through cuttings is possible → Spread this knowledge.

The cuttings need constant care, as they need to be watered frequently over many weeks. This requires attention and labour → The long-term benefits outweigh the labour invested.

Key reference(s): Antsonantenainarivony O. Goum (2015) Guide pratique pour la bouture de samata (*Euphorbia stenoclada* Baill.) dans la partie littorale de la région Sud-Ouest de Madagascar. http://www.sulama.de/index.php/en/literature/reports-english.html • Johanna Goetter et al. (2015) Degradation of the Important Fodder Tree *Euphorbia stenoclada* in Southwest Madagascar and Approaches for Improved Management. Poster presented at the conference Tropentag 2015, September 16 - 18, Berlin, Germany. DOI: 10.13140/RG.2.1.3734.7445 • Johanna Goetter and Regina Neudert (2016) New rules are not rules: Privatization of pastoral commons and local attempts at curtailment in southwest Madagascar. International Journal of the Commons (10:2). DOI: 10.18352/ijc.743
Contact person(s): Johanna Goetter, Brandenburg Technical University, Germany. goetter@b-tu.de

left: Participants simulate their livelihood activities on maps. (Photo: Jacques Rakotondranary, July 2014)
right: The participants explain their choices to the researchers. (Photo: Jacques Rakotondranary)

Role-Playing Games in Natural Resource Management

Madagascar

Participatory simulation to foster stakeholder dialogue in natural resource management (NRM), conciliate resource conflicts and facilitate participatory land use planning

Two role-playing games were designed to understand land users' livelihoods strategies in both “normal” but also in times of drought events and cattle raids. The aim was to find out how, and why, livelihood decisions differed between household types in south-western Madagascar. Under the role-playing methodology, land users actively participate through discussing livelihood strategies, negotiating interests, and planning for the future. The methodology proved to be very dynamic, interactive and useful.

The SuLaMa project is a five-year Malagasy and German research project involving an interdisciplinary team (consortium) that aimed at developing sustainable land use techniques in south-western Madagascar. To validate soft-models that fed into computer-based models on land use change in the region, four workshops were held in four villages on the Mahafaly Plateau. Two groups of land users, with twelve participants each, worked simultaneously in each village: a total number of 96 participated. The games, ‘Livelihood Game’ and ‘Livestock Game', were designed to foster both scientific knowledge production on land use systems, and dialogue with land users. The essence of the methodology is that participants assume the roles of different household types and simulate their annual livelihood activities on a village map. The four household types differed from relatively wealthy (owning cattle; a lot of land) to poor (no cattle, little land). Each household type was represented by two or three participants and roles were allocated randomly.

The 'Livelihood Game' covers a time span of four fictive years. Each round represents the household’s annual subsistence decisions. In contrast, the 'Livestock Game' covers just one year with each round encompassing one of three seasons. In the 'Livelihood Game', players have a set of activity options: for example they can locate fields on the map and choose how to cultivate them. Moreover, additional activities like livestock keeping, charcoal making, paid work, collecting/hunting or educating children are available to them. The 'Livestock Game' concentrates on grazing and animal feeding decisions. Each decision is visualized by pictured cards, tokens and symbols - and grazing areas are mapped. While this participatory simulation remains a game, it would be feasible to integrate the methodology into a land use planning process.

Initially, the joint interdisciplinary team conducted a baseline survey using Rapid Rural Appraisal tools to gain a general understanding of local socio-ecologic systems. Following this, a quantitative household survey was carried out in several villages (665 households in total) to analyse household composition and structures. Based on the results, researchers designed the structure of the role-playing games.

A crucial precondition was that local communities were well-informed and participation was voluntary. This was achieved by an ‘announcement tour’ where timings were adapted to social, cultural and labour schedules of the local population. The communities were invited to determine the participants according to specific criteria. Participants had to be those who practiced the typical livelihood activities of agriculture and livestock keeping, and who contributed to household decision-making. Furthermore, a balance in terms of gender, age and lineage was requested.

Location: Mahafaly Plateau, South-Western Madagascar, Betioky-Atsimo
Approach area: 1,000 - 10,000 km^2
Type of approach: project / programme based
Focus: participation, land use simulation
WOCAT database reference: A_MAD002en
Related technology: none
Compiled by: Maren Wesselow, Chair of Sustainability Science and Applied Geography, University of Greifswald,
Date: July / August 2014, updated June 2016

SuLaMa

ERNST MORITZ ARNDT UNIVERSITÄT GREIFSWALD

Problem, objectives and constraints

Problems:
Lack of communication and negotiation between resource users and scientists. Absence of governmental actors in long-term planning and decision making and weak governance. Lack of regulations for the use of scarce resources.

Aims / Objectives:
The community workshops were held in order to (1) validate the researchers' systems understanding about rural livelihoods and land use activities, and to (2) discuss land users' responses to drought events and cattle raids.

Constraints addressed

	Constraints	**Treatments**
Social / cultural / religious	In this rural region, governmental decision-making authorities are mostly absent. Decision-making processes in the local communities follow traditional hierarchies and structures. Men and old people generally have a greater decision-making power than women and young people.	External actors organized the workshops. They controlled group composition so that it was balanced in terms of gender, age, and lineage.
Other	Rural livelihoods in the Mahafaly region are vulnerable. Rainfed agriculture and livestock keeping constitute the mainstay of virtually all households. Low and unpredictable precipitation limits agricultural production. Recurrent droughts lead to harvest failures and put a major threat to rural livelihoods. Moreover, people are faced with the problem of organized and armed cattle raiders. In fear of being robbed, herders adjust their grazing grounds and paths.	Participants could relate the simulation to real-life. They were enabled to analyse their household management systems and to develop coping strategies to address drought periods. Participants discussed commonly how to respond to the risk of cattle raids in the region.

Participation and decision making

Stakeholders / target groups

land users, individual, groups

Approach costs met by:

- International (German Ministry of Education and Research (BMBF)) 100%

Total **100%**

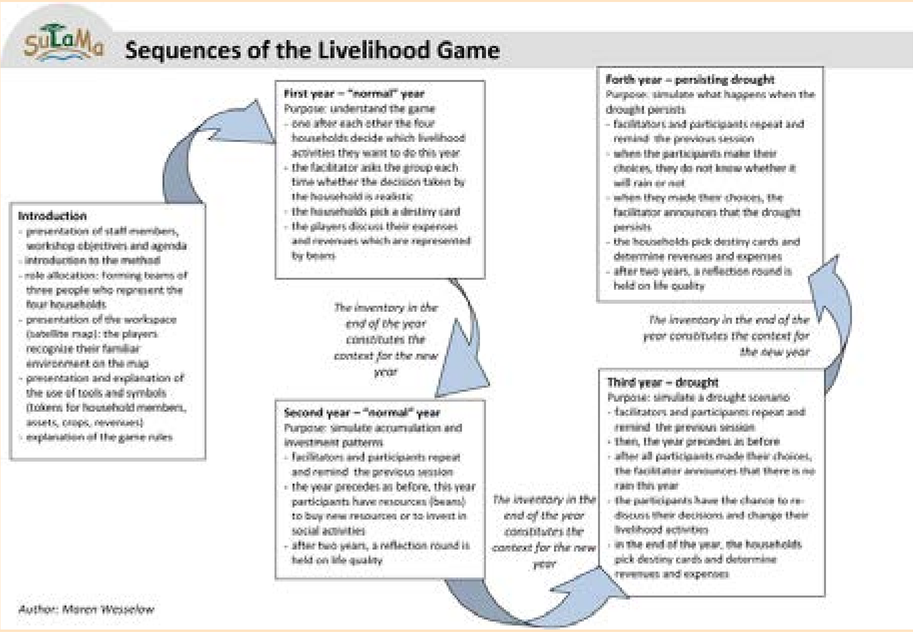
Annual budget for SLM component: US$ 2,000-10,000

Decisions on choice of the Technology: Mainly by land users supported by SLM specialists
Decisions on method of implementing the Technology: By SLM specialists alone (top-down)
Approach designed by: International specialists, land users, national specialists
Implementing bodies: International (German-Malagasy research consortium), local community / land users (land users from the villages), international non-government (World Wild Fund (WWF)), local government (district, county, municipality, village etc.), traditional village authorities.

Land user involvement

Phase	**Involvement**	**Activities**
Initiation/motivation	None	
Planning	None	
Implementation	Interactive	Villagers participated in the workshops. They received community remuneration as compensation for their time.
Monitoring/evaluation	Interactive	After the workshops, participants were asked to give feedback on the methodology.
Research	None	

Differences between participation of men and women: No
Involvement of disadvantaged groups: Yes, great; when selecting participants, a balance in gender, age and lineage was required.



Organogram:
The flow chart demonstrates the different sequences of the Livelihood Game as it was played in the workshops of 2014. After an introduction, four years were simulated. Each year has a different purpose: years one and two can be classified as 'normal' years, whereas years three and four are drought years. While year one serves to introduce and understand the game, the second year is to simulate accumulation and investment patterns. The third year constitutes a drought year - meaning harvest failure for the households. In the fourth year, participants simulate their behaviour in the scenario of a persisting drought (Maren Wesselow).

Technical support

Training / awareness raising: Training was provided for research assistants who facilitated and documented the workshop. Training was on-the-job. During the workshop sessions, land users gained understanding of the interdependencies of land use and conservation practices and came to reflect on the livelihood strategies in their villages.
Advisory service:
Name: Participatory simulations, role-playing games
Key elements:
1. Taking on another households' role
2. Developing livelihood strategies in response to different scenarios
3. Discussion, communication and negotiation

Research: Yes, considerable research support.
An international research consortium conducted the role-playing game workshops to validate human decisions in their land use models. Topics covered include households' livelihood strategies in “normal” times and in times of difficulties. Mostly on station research. However, the approach can be applied/ adapted for various purposes.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Paid in cash. Participants were paid an expense allowance for the workshop days.
Input:

- equipment: maps, toolkits with pictured cards, tokens, etc. Fully financed

Credit: Credit was not available
Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
technical	Regular observations by project staff: data on land use practices were collected
socio-cultural	Regular observations by project staff: data on human well-being and social conventions (traditions, rituals) were collected
economic / production	Regular observations by project staff: data on expenses and revenues were collected
area treated	Regular observations by project staff: spatial decisions were visualised and marked on maps
management of Approach	Regular observations by project staff: in each of the 4 villages 24 land users took part in the workshops
no. of land users involved	Regular observations by project staff: in each of the 4 villages 24 land users took part in the workshops

Changes as result of monitoring and evaluation: There were few changes in the approach. To synchronize the process in the two groups within a village, it was essential to have one observer who could move between the two groups and detect differences. For instance, it was observed that while one facilitator preferred to gather all participants around one big table, the other one arranged separate tables for each household. After the workshop sessions, observers, facilitators and documenters discussed the process and crosschecked the results of different groups. Eventually, it was agreed that it was better to have all participants around one big table. Also household assets, such as poultry or houses, were adopted in the game by the players.

Impacts of the Approach

Improved sustainable land management: Yes, little; Participants stated that they learned about each other's livelihood strategies and the long-term impacts. One participant in Andremba stated (2014): "For us this game is like a lesson that makes us understand what happens in our lives. It is a reflection game that makes us think about our lives and our way of life with our subsistence activities and income sources."
Adoption by other land users / projects: No. So far the approach has only been tested once by researchers. However, interested organizations may adopt and develop the method in the future.
Improved livelihoods / human well-being: No. The approach primarily triggers land user involvement, but does not directly affect their livelihoods.
Improved situation of disadvantaged groups: Yes, little. People of mixed age, gender and lineage participated in the simulations.
Poverty alleviation: Yes, little. Although there is no direct linkage between participation and poverty alleviation, the approach may raise awareness of development and conservation issues as well as community learning and empowerment.
Training, advisory service and research:

- Training effectiveness
  Land users, research assistants: good
  So far the approach was only applied with a group of land users. It might be feasible to also involve SLM specialists, agricultural advisors, and decision-makers in the role-playing game.
- Advisory service effectiveness:
  Land users excellent
  The approach is open and flexible. It can involve different kinds of protagonists.
- Research contributing to the approach´s effectiveness:
  Greatly. The role-playing games were derived from a participatory research process which aimed at creating computer-based land use models.

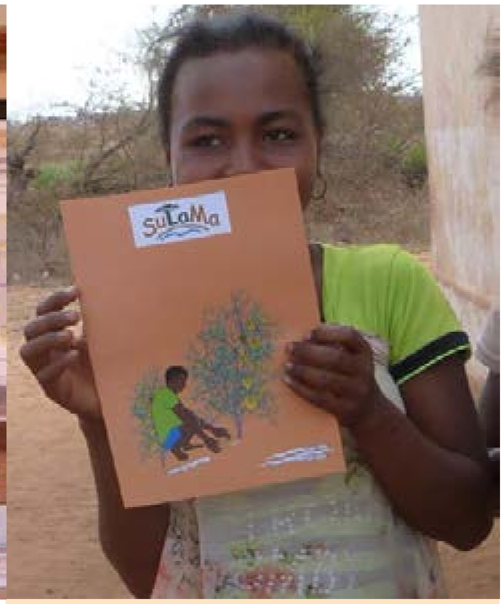
Land/water use rights: Resource and land ownership was a topic during the role-playing games. Problems and conflicts could be detected and discussed, but were not always solved.
Long-term impact of subsidies: not applicable (the workshop was only one event in 2014)

Conclusions and lessons learnt

Main motivation of land users to implement SLM: 1) Rules and regulations (fines) / enforcement: The approach may help to negotiate rules and regulations in natural resource management and initiate environmental consciousness among land users. It also brings about understanding of local livelihoods for external actors. 2) Participation of land users in science and implementation processes as well as communication between local communities and external actors.
Sustainability of activities: No. The land users can`t sustain the approach activities without support. As the methodology needs preparation and facilitation, some method specialists are required to accompany the process.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
The role-playing game became vivid and lively by using visualization and communication tools. The tools not only helped to capture the whole system's complexity and open-up discussions, they also ensured mutual understanding and synchronized different agents' perception. Pictures also helped to achieve a common understanding beyond language barriers. In a region with a high illiteracy rate, these visualization tools can be regarded as measures of empowerment as no writing or reading skills are necessary to take part in the game. Thus, the method is a dynamic and interactive tool for stakeholder integration and awareness raising.	The methodology is time-consuming and brings no direct or sudden benefits for land users → The method could potentially be changed so that results are less research-oriented and more visible to the participants. New technologies or alternative livelihood activities could be simulated during the game.
The participants understood and generally accepted the game rapidly. They confirmed that they had recognized that it was not just a game - but a simulation of reality. As all the activities referred to the people's everyday lives, no lengthy introduction or explanation was necessary to start the game. People seemed to feel comfortable in their "roles" and spoke freely about their household decisions. They were able to actively take part in the game not only by answering the questions but also by manipulating the game materials on their own. One participant from Efoetse stated (2014): "This game is easy, because it refers to our daily lives, not to something you have created for yourself. This is the reality of our daily lives."	It must be mentioned that a lot of investment and preparation is needed for conducting the workshop successfully. The role-playing game not only requires very specific materials and tools, but also a lot of time is required for development, preparation, team training, testing and on-site implementation. If the time needed for carrying out the game cannot be planned and tested carefully in advance, it may lead to frustration and disappointment → The benefits of this approach need to be justified and proved to donors and the extension / advisory services to convince them to invest.
	Though the methodology was generally accepted and understood, it turned out to be challenging for facilitators and documenters. It requires high communication skills, and understanding of local conditions and the willingness to listen to the local people in order to build trust among the group → To become good facilitators, capacity building and training of extension workers or advisors is needed.
	The role-playing games methodology is laborious to design and prepare, it usually needs one dedicated institution to initiate and coordinate the workshops → The only option for continuing this methodology is if a generally-accepted and professional organisation can be found to take on the responsibility in the long term.

Key reference(s): Wesselow et al. (2015) Participatory Gaming for Sustainable Land Management in the Mahafaly Region. A Practical Guide for Researchers and Practitioners. Sustainable Land Management in Madagascar (SuLaMa) project.
http://www.sulama.de/files/products/WP5_Product3_Participatory_Gaming_for_SLM_eng.pdf
Contact person(s): Maren Wesselow, Ernst-Moritz-Arndt University of Greifswald, Germany. maren.wesselow@uni-greifswald.de



left: Presentation of a storyline on the use of composted manure for home gardening during a village workshop. (Photo: K. Brinkmann)
right: Distribution of comics on the subject of sustainable yam harvesting to the local population. (Photo: K. Brinkmann)

Increasing environmental awareness using comic-style illustrations as a visual communication tool

Madagascar

Communicating and transferring scientific results and recommendations about sustainable land management to local people

The central aim of this approach was to increase environmental awareness in the Mahafaly region of southwestern Madagascar using visual communications tools. Comic-style illustrations were originally designed to communicate scientific recommendations on sustainable land management (SLM) and to ensure knowledge transfer from scientists to local people.

Visual communication, based on pictures, drawings, movies, sequential images and posters plays a vital role in countries where many people are illiterate. Another advantage is its easy reproduction in comparison to oral communication. It may also transfer knowledge where oral communication fails because of linguistic barriers or simply because complex narratives and messages are easier to explain visually than orally. In the context of a participatory research project to support SLM on the Mahafaly Plateau in southwestern Madagascar, comic-style illustrations of visual narratives were used to focus on environmental problems and SLM strategies. Since cross-cultural differences arise in “visual languages” globally, the visualization style needs to be carefully selected. Furthermore, misunderstanding of visual narratives may occur when objects are drawn not realistically enough, or if the statement is abstract or only presented from a scientific The central aim point of view. To avoid misinterpretation and increase readability and local acceptance, the style of comics was specifically designed for the conditions in rural Madagascar using a traditional Malagasy art style (sepulchre art in the form of “Aloalo” tomb sculptures). Comic illustrations were prepared to show the impact of different land use practices on the environment and local livelihoods using two contrasting stories/scenarios. The “red story” depicts a worst case scenario of unsustainable practices that are often applied by local inhabitants and the “green story” shows an example of a best case scenario based on an alternative, sustainable land management option recommended by scientific experts. To keep the stories simple and understandable, there was a focus on scientific key messages which can be easily transformed into visual narratives - and technical details were left aside.

The six year (2011-2016) transdisciplinary research consortium of Malagasy and German universities was initiated in the Mahafaly region of southwestern Madagascar in order to support sustainable land management (SuLaMa = Sustainable Land Management in southwestern Madagascar). Based on scientific research regarding the diversity and local use of forest resources and SLM practices in animal and crop husbandry, key messages and recommendations, which were easy to implement, were formulated by the scientific experts. Two examples of overused natural resources and one example of a neglected soil improvement practice were chosen for comic-style illustrations and transformed to visual narratives. These are (i) sustainable harvesting practice of wild yams (*Dioscorea bemandry*); (ii) composting of manure and its application to improve soil fertility and yields in home gardens; and (iii) sustainable utilization of the succulent tree *Euphorbia stenoclada* (called 'samata' in the local dialect) as supplementary forage for livestock. During an inception phase for the implementation of visual narratives in the study region, different drawing styles were tested and assessed to gather information on the local perception of art. Drawing styles showing the highest acceptance rate and readability were subsequently used to prepare the comics. The comics were printed on robust clay coated paper and handed out to local inhabitants during larger village workshops, where the different stories were presented and discussed.

Location: Atsimo-Andrefana (South-West Madagascar), Toliara II
Approach area: 1,000 - 10,000 km^2
Type of approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: A_MAD003en
Related technology: T_MAD002en (Sustainable propagation of the fodder tree (*Euphorbia stenoclada*: “samata”))
Compiled by: Tobias Feldt, Animal Husbandry in the Tropics and Subtropics, University of Kassel, Germany, tropanimals@uni-kassel.de,
Date: 1st October 2015, updated April 2016

Problem, objectives and constraints

Problems:
The approach area is characterized by low agricultural production, lack of technical knowledge, low education levels and conflicts over resource use.

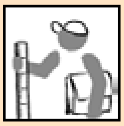
Aims / Objectives:
Comic-style illustrations were designed for environmental education purposes to communicate scientific results and recommendations on sustainable land management and ensure knowledge transfer from scientific experts to local people. It is the general aim of the approach to raise awareness about sustainable land use and environmental protection, and therefore to improve both people's livelihoods and efficiency in the use of natural resources.

Constraints addressed

	Constraints	Treatments
Workload	Local people often do not see direct benefits from increasing workloads: e.g. by more careful harvesting of forest products, the cleaning of livestock enclosures, or the utilization of manure for soil amelioration.	The approach aims to show plainly the positive and sustainable impact of the alternative practices and the effect on people's livelihoods.
Social / cultural / religious	Cultural reservation towards the utilization of animal dung, thus 'renouncing' – and missing out on the benefits of - one of the key methods of soil amelioration. Reluctance to handle animal faeces and therefore rarely cleaning their night enclosures significantly increases the risk of epizootic diseases and parasitic infections.	The comic drawings attempt to demonstrate how simple measures may have a sustainable impact in improving people's livelihoods in many ways. They will at best be food-for-thought to reconsider culture-based practices that are not good SLM practice.
Other	The concept of some natural resources being finite is not very widespread among the local population.	The approach may help local people to become more aware of this problem and to induce the establishment of more sustainable land use practices.
Legal / land use and / water rights	With regard to the sustainable utilization of fodder trees, land ownership conflicts may arise as most of these trees around settlements stand on private ground – but without clear demarcation.	Where currently there only exist single cactus plants or other hardly recognisable natural markings between plots, clear boundary lines between those plots could be illustrated as a good alternative in the respective comic

Participation and decision making

Stakeholders / target groups


SLM specialists / agricultural advisors


teachers / school children / students


land users, groups

Approach costs met by:

- government (German Federal Ministry of Education and Research, BMBF) 100%

Total **100%**

Annual budget for SLM component: US$ 2,000-10,000

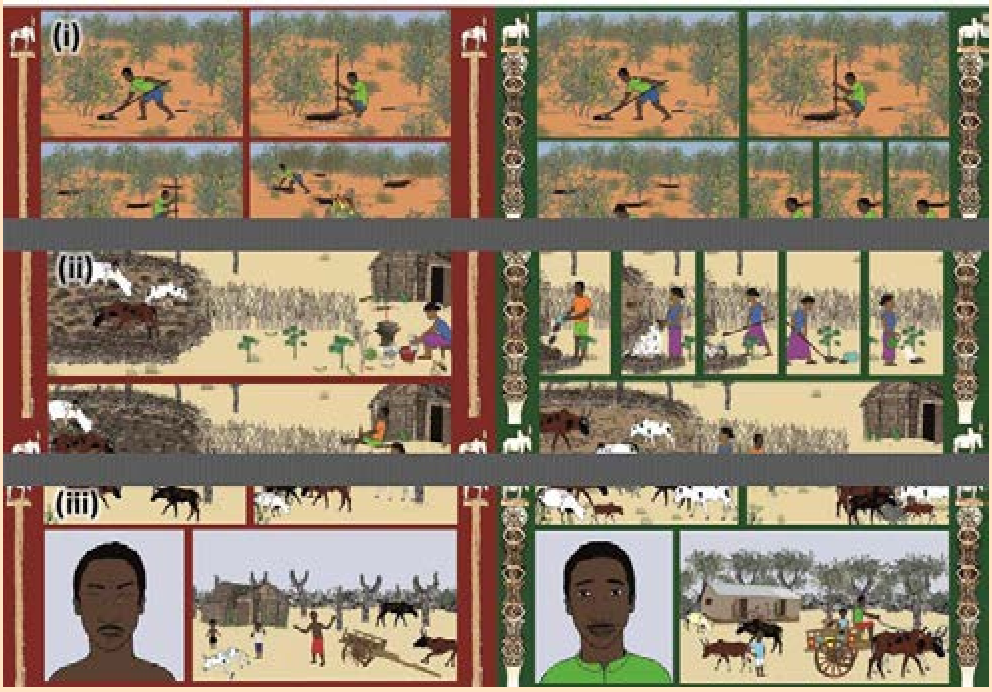
Decisions on choice of the Technology: mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology: mainly by SLM specialists with consultation of land users
Approach designed by: national specialists, international specialists
Implementing bodies: international, international non-government, local government (district, county, municipality, village etc) (municipality, village), local community / land users

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	None	
Planning	Interactive	data surveys, questionnaires, group discussions
Implementation	Payment/external support	village workshops to present the comics and to explain the storylines
Monitoring/evaluation	Interactive	stepwise evaluation and improvement of comic understanding and acceptance by land users and the community
Research	Passive	

Differences between participation of men and women: Yes, moderate. Livestock related topics were addressed to male farmers as they are mainly involved in livestock husbandry.

Involvement of disadvantaged groups: No



Organogram:
Extracts of three storylines on (i) yams harvesting, (ii) manure composting and (iii) the utilization of 'samata' (*Euphorbia stenoclada*) (© D. Weiss)

Technical support

Training / awareness raising: Training provided for land users, field staff/agricultural advisors. Training was through demonstration areas and public meetings
Advisory service:
None
Research: Yes, significant level of research. Topics covered include sociology, technology, economics / marketing, ecology. Mostly on-farm research.

External material support / subsidies

Contribution per area (state/private sector): None
Labour: Voluntary
Input:
- Equipment: drawing material (pens and paper). Fully financed
- Travel expenses: field trips of the comic illustrator. Fully financed

Credit: Credit was not available
Support to local institutions: Yes, good support with finance, training, equipment, transport

Monitoring and evaluation

Monitored aspects	Methods and indicators
No. of land users involved	*Ad hoc* observations by project staff and land users: comics were distributed to land users and discussed with representatives of 15 villages.
Technical	Regular observations by project staff: data on land use practices were collected.
Socio-cultural	Regular observations: data on human well-being and social conventions (customs, traditions, rituals) were collected.
Technical	Regular measurements by project staff
Evaluation	*Ad hoc* observations by project staff: evaluation of understanding and acceptance of comics

Changes as result of monitoring and evaluation: The understanding of the comics, their acceptance and the possible implementation of the land use approaches still have to be investigated during a follow-up evaluation process.
There were few changes in the technologies. This still needs to be investigated during the evaluation process.

Impacts of the Approach

Training, advisory service and research:

- Training effectiveness:
  Land users and teachers: good
  School children / students: excellent
  This still needs to be further investigated during the evaluation process.
- Advisory service effectiveness:
  Teachers and land users: good
  School children / students: excellent
  This still needs to be further investigated during the evaluation process.
- Research contributing to the approach´s effectiveness: Significant
  During the six-year term of the original project, researchers gained a deep insight into the daily routine and work regimes of the local population. The approach was therefore based on this knowledge and aimed at some of the major problems identified.

Land/water use rights: A hindrance to the implementation of the approach. Some contents presented in the comic drawings, such as that regarding the sustainable utilization of fodder trees, can conflict with land ownership as most of the trees around settlements stand on private ground. Boundary lines between these plots, often only consisting of single cactus plants, or other natural markings, may not be recognizable to outsiders but have to be included into the comics to avoid misunderstandings. The approach did reduce the land/water use rights problem (low). This still needs to be investigated during the evaluation process.

Long-term impact of subsidies: No subsidies were used.

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production; increased profitability, improved cost-benefit ratio; environmental consciousness, health; well-being and livelihoods improvement; prestige / social pressure

Sustainability of activities: Yes the land users can sustain the approach's featured activities without support. Land users can implement the technologies presented in the comics without further help. However for additional applications, new case-specific comic drawings will have to be prepared as the land users may not be able to transmit messages about other practices.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Structured surveys carried out after the distribution of the material showed that local people understood and generally accepted the comic stories.	Considerable investment and preparation is needed to implement comic-style illustration methods. Comic strips have to be provided in sufficient volume and quality, as reprinting is too expensive for local communities.
This approach has great potential for communication of any knowledge and not just restricted to scientific subjects. It should be further supported and widely used, especially (but not only) in rural areas with low literacy levels. Pictures have a great impact on people's perception and messages can be more easily memorized.	In-depth knowledge and understanding of local traditions and practices is mandatory as apparently minor (incorrect) details and finesses may hamper the comprehensibility and acceptance of the comic strips.
The more the pictures correspond with reality, the better is the "readability" and identification. The fewer the needless details shown, the better the recognition.	The design of comics that are both comprehensive and action-stimulating for the local population requires a lot of time consuming preliminary work. If available, local artists and organizations should be called in and involved in this process to make sure, at the same time, that the approach can be sustained and further developed by local stakeholders.
This environmental education material offers various possibilities for application, e.g. in schools or during village meetings. It can be used by the local communities for a long period.	
As soon as an appropriate illustration style is found, various topics can be added and more complex subjects can be depicted in greater detail. Individual comic strips may form the base for a more comprehensive but still understandable and adoptable compendium.	

Key reference(s): Andriamparany, J.N. (2015) Diversity, local uses and availability of medicinal plants and wild yams in the Mahafaly region of southwestern Madagascar. PhD thesis, University of Kassel, Germany • Andriamparany J.N. et al. (2015) Modelling the distribution of wild yam species in southwestern Madagascar using biotic and abiotic factors. Agriculture, Ecosystems and Environment 212, 38-48. • Feldt, T. (2015) Interrelatedness of grazing livestock with vegetation parameters and farmers' livelihoods in the Mahafaly region, southwestern Madagascar. PhD thesis, University of Kassel, Germany. • Feldt, T., Schlecht, E. (2016) Analysis of GPS trajectories to assess spatio-temporal differences in grazing patterns and land use preferences of domestic livestock in southwestern Madagascar. Pastoralism: Research, Policy and Practice 6 (1) • Goetter, J.F., Neudert, R., (accepted) New rules are not rules: privatization of pastoral commons and local attempts at curtailment in southwest Madagascar. International Journal of the Commons. • Hanisch, S. (2015) Improving cropping systems of semi-arid southwestern Madagascar under multiple ecological and socio-economic constraints. PhD thesis, University of Kassel, Germany • Weiss, D. (2014) Visual communication: a promising approach in developing countries? Bachelor thesis, University of Kassel, Germany.
Contact person(s): David Weiss, Kirchstraße 18, D-37214 Witzenhausen, Germany, mail@david-weiss.com, http://david-weiss.com • Tobias Feldt, Animal Husbandry in the Tropics and Subtropics, University of Kassel, Germany. tropanimals@uni-kassel.de, http://sulama.de

left: Researchers introducing the procedure of the venn diagram to local participants of the MARP study. (Photo: Jutta Hammer)
right: Participant of the MARP study shows the historic development of the region, using beans on a map (Photo: Jutta Hammer)

Rapid and Participatory Rural Appraisal Study (MARP)

Madagascar - *Etude de Méthode Accélérée de Recherche Participative (MARP)*

The MARP approach, as reported here from Madagascar, is a participatory, but rapid, interdisciplinary assessment of local perspectives on livelihoods and natural resources use.

'MARP' is a methodology for assessing local situations that is both participatory and rapid. It was used during the initial stage of a six-year research project (2011-2016) on sustainable land management (SLM) in Madagascar conducted by a consortium of German and Malagasy universities in collaboration with a NGO. The aim of the MARP study was to facilitate the local population to express their perspectives on local livelihoods and natural resource use. The approach sought to integrate local voices into project planning. Specific objectives were (a) to build a link between German and Malagasy researchers from different disciplines, (b) to train them in the MARP methodology, (c) to understand the broad outlines of subsistence strategies, and (d) to explore the diversity of social and environmental situations in the Mahafaly Plateau region.

The MARP methodology facilitated an exchange between the local population (including land users and village representatives) and researchers about selected themes. Participants were invited to express themselves about their lives, social and ecological conditions and their use of natural resources. Four villages were chosen for the study, two at the coast and two on the plateau. The researchers were divided into two groups. Each group was accompanied by a facilitator and translators and each collected data in one village at the coast and one village on the plateau. Different techniques were applied to gather the information including semi-structured interviews, social maps, calendars (demonstrating cropping systems and historic developments etc), venn diagrams, and transect walks. In group discussions among researchers, information was triangulated and validated. After assessing a village, researchers called its villagers for feedback and discussion about the collected data. In this meeting the researchers presented a summary of results on local livelihoods, cropping systems and socio-cultural events, to discuss how accurate they were.

The MARP study was developed and carried out by researchers from various disciplines including agriculture, livestock farming, silviculture, economics and human geography. It was divided into four phases, (1) an introductory workshop and technical training, (2) data collection, (3) data analysis, and (4) a final workshop. In phase (1) two external experts in the MARP techniques introduced these to the participating Malagasy and German researchers in a four-day workshop. Phase (2) and (3) were implemented in the study region over a four-week period. In phase (4) the MARP study closed with a final workshop in the regional capital Tuléar, where results were discussed with regional stakeholders.

The local population played a particularly important role in the MARP study through providing key information about livelihoods and natural resource use etc. People from different clans and lineages, social status and both men and women were strategically included. The MARP study group comprised 27 people who participated in the assessment: they included researchers, facilitators, socio-organizers, and translators. Researchers had to develop contact with the local population, to learn from their insights, to collect and analyse data and to discuss the results with them. The facilitators' role was to give directions to the teams during the study process. Social organizers dealt with equipment and accommodation, and translators accompanied non-native researchers during the information-gathering process.

Location: Mahafaly Plateau, south-western Madagascar, Beheloke-Atsimo
Approach area: 1,000-10,000 km^2
Type of approach: project/programme based
Focus: mainly on other activities
WOCAT database reference: A_MAD004en
Related technology: none
Compiled by: Nadine Fritz-Vietta, University of Greifswald
Date: 12th February 2016, updated 18th March 2016

SuLaMa

Problem, objectives and constraints

Problems:
Lack of dialogue between researchers and local population, researchers' lack of knowledge/ specific insights into community life, researchers' lack of knowledge about stakeholder participation

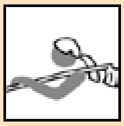
Aims / Objectives:
The aim of the MARP study was to start dialogue between the local population and researchers about various aspects of local livelihoods including: subsistence strategies in agriculture and livestock keeping, natural resource use, the socio-cultural context, and the local economy. Another aim was to provide information on community perspectives for the research project's planning process, and to start interdisciplinary exchange.

Constraints addressed

	Constraints	Treatments
Technical	Lack of water and electricity in the field.	Organization of enough water, organization of generators, adaptation to conditions by not using computers, but reporting through handwritten notes.
Workload	Need of researchers to adapt to local/regional conditions, to learn a new methodology and to collect viable information all at once; demand on the local population to spend time and effort on communication and knowledge exchange.	Scheduling enough time for the study and offer also leisure time for all participants
Social / cultural / religious	The cultural differences between international/ national researchers and local population proved to be a challenge for the implementation of the MARP study (Malagasy researchers participating in the process mainly originated from a different region in Madagascar).	Awareness-raising among the researchers to adapt to local cultural norms and engagement of personnel from the region to support the communication process.
Institutional	Researchers were not familiar with the MARP methodology and the regional context.	Offering an introductory workshop at the beginning of the MARP study and supporting the learning-by-doing process by facilitators.

Participation and decision making

Stakeholders / target groups



land users, individual / groups

Approach costs met by:

– International (German Ministry of Education and Research, BMBF)	100%
Total	**100%**

Annual budget for SLM component: US$ 2,000-10,000

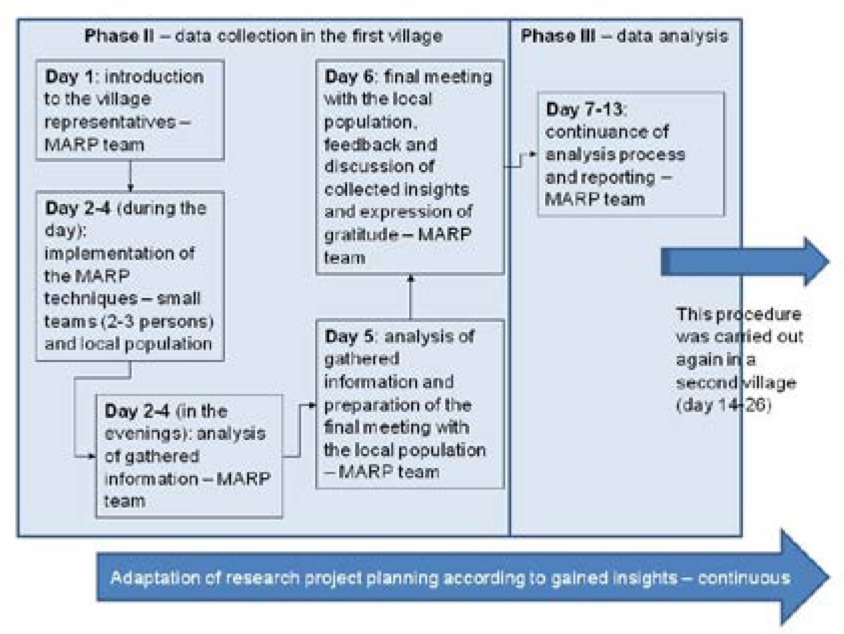
Decisions on choice of the Technology: By SLM specialists alone (top-down).
Decisions on method of implementing the Technology: Mainly by SLM specialists with consultation of land users.
Approach designed by: International specialists.
Implementing bodies: National non-government (Madagascar National Parks), international (research consortium), international non-government (WWF), village representatives, local community / land users.

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Passive	
Planning	Interactive	Local decision-makers were involved in the planning process; they took decisions about the study procedure and payment.
Implementation	Interactive	Various persons from the local communities; information exchange and provision of local insights.
Monitoring/evaluation	Payment/external support	Various persons from the local communities were involved in monitoring of the results; feedback and discussion.
Research	Passive	

Differences between participation of men and women: Yes, little. More men participated in group meetings. According to local customs, men dominate village meetings, women do not have the right to speak. However, efforts were made to involve women in the study through approaching groups of women in the villages.

Involvement of disadvantaged groups: Yes, moderate. People from different lineages, status and age were deliberately involved.



Organogram: Flow chart shows the MARP study procedure exemplified by the first village. Right after the introductory workshop and technical training the MARP team went off into the field. It spent six days in the first village starting with an introduction followed by a structured guidance through the MARP exercises and reflection on gathered information. The MARP study process in the first village closed with a final meeting of villagers and the MARP team in order to discuss the outcome. Subsequently the MARP team moved to another place for data analysis and reporting before preparing the stay in the second village. (Nadine Fritz-Vietta)

Technical support

Training / awareness raising: Training focused on MARP/ Rapid and Participatory Rural Appraisal Methodology in the field of local livelihoods and natural resource use for researchers; local population was provided with awareness raising about the research project and the way how to participate in the research process.

Advisory service: Key elements: 1. Applying a multitude of visual and verbal appraisal techniques; 2. Triangulation of information to guarantee validity; 3. Starting dialogue, communication and discussion concerning local livelihoods.

Research Yes, considerable research support. Topics covered include sociology, economics / marketing, natural resource use. The aim was to gain a collective picture about local livelihoods, subsistence economy, and natural resource use. Mostly on-farm research.

External material support / subsidies

Contribution per area (state/private sector): No

Labour: Voluntary with reward. At the final meeting as expression of gratitude for participation some money was transferred to the community heads to be shared in the village.

Input:

- Equipment: Flip charts/ paper sheets, markers, beans, generators, computer. Fully financed
- Logistics: Drinking water, food for the team, transport. Fully financed

Credit: Credit was not available.

Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
Management of Approach	Ad hoc observations by project staff: data for project implementation and evaluation.
No. of land users involved	Ad hoc observations by project staff: data on stakeholder participation in conservation activities.
Socio-cultural	Regular observations by project staff: data on history and socio-cultural aspects in natural resource use. Regular measurements: data from venn-diagram
Economic / production	Regular observations by project staff: data on local livelihoods and subsistence economy. Regular measurements: data from social mapping and crop calendars etc.

Changes as result of monitoring and evaluation: There were several changes in the approach. Based on the data in the first two villages studied at the coast, other villages were chosen for the second set on the plateau; this was a result of social and economic interdependencies between coastal and plateau villages; furthermore, the set of applied techniques and the questions posed in the semi-structured interviews were adapted.

Impacts of the Approach

Improved sustainable land management: No; the focus of the MARP study was to gain insights into local people's perceptions regarding livelihoods and natural resource use rather than helping local land users to improve sustainable land management – though improved SLM was the aim of the overall research project to which the study contributed.
Adoption by other land users / projects: No
Improved livelihoods / human well-being: No; the aim was to start dialogue about local livelihoods (including well-being) and natural resource use between the local population and researchers rather than having a direct impact on livelihoods: the overall research project was intended to have an impact on local livelihoods.
Improved situation of disadvantaged groups: Yes, little; socially and economically disadvantaged people participated in the MARP study and explained their situation.
Poverty alleviation: No; the aim was to trigger communication processes between local people and researchers about local people's socio-economic situation rather than having a direct impact on poverty.
Training, advisory service and research:

- Training effectiveness:
  Land users: fair; international and national/local researchers: good
  Land users participated in various MARP techniques, it was "learning-by-doing"; researchers mainly benefitted from the technical training at the beginning of the MARP study and then applied the various methods in the field.
- Methodological effectiveness:
  researchers: good. Researchers gained relevant insights into local people's livelihoods and natural resource use, which was the basis for the subsequent research planning.
- Research contributing to the approach's effectiveness:
  Strongly
  Research is a main pillar of the MARP study

Land/water use rights: Existing land ownership was part of the MARP study. Through applying the mapping techniques land use rights and water rights were illustrated by local participants
Long-term impact of subsidies: Not applicable.

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Affiliation to movement / project / group / networks; Environmental consciousness; Participation, dialogue.
Sustainability of activities: No the land users can`t sustain the approach activities without support. The MARP study was mainly conducted by researchers who were trained in the application of techniques. If other stakeholders are interested in continuing this approach they need technical training.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
From the land users' point of view the MARP study offered the opportunity of starting dialogue with researchers. By participating and responding to researchers' questions they reflected about own livelihoods and their way of living. Local people took the experts' role in the study by explaining their perspective on local livelihoods and natural resource use. The MARP methodology also facilitated the inclusion of everybody who was willing to participate, including illiterate and socially disadvantaged people.	In some cases communication barriers (lack of language skills) hindered the process. This was true for communication between local people and researchers - but also among German and national/local researchers. Consequently a great number of translators were needed, which increased the number of people participating in the MARP study. Some researchers were new to the area or even to the country and had to work with a high amount of complex new information, while being required to adapt to local conditions. This led to a very heavy workload. Concerning the MARP study process, local people were not always available for enquiry, which was difficult to manage for the MARP team. → A session on cultural awareness should be integrated into the introductory workshop. The MARP study should be announced early enough to both the researchers (so that they can prepare) and the local people (so that they can plan their availability for the study).
A team building process was initiated by the MARP study. A team of interdisciplinary researchers from Madagascar and Germany came together to work towards a common goal. Communication between disciplines was fostered and team members learned how to overcome cultural differences. The MARP team had the opportunity to gain hands-on experiences with the MARP methodology. The MARP study facilitated mutual exchange between local people and researchers. By spending time in the field together with local people, researchers started dialogue with them and thus gained important insights into local livelihoods and natural resource use. With the process of joint reflection on gained insights, the researchers had valuable information at hand to design the following research process (including interdisciplinary approaches). Participants also benefitted from an improved intercultural understanding.	Local people were only involved in a late stage of the MARP study's development process. Although village representatives were consulted before the MARP study implementation, local people only received the information about the study when it had already started. Local people did not see any direct benefit of participating in the MARP study. They rather felt that they were obliged to spend valuable hours of work for the study. People perceived a disturbance to their village life through a group of foreigners with a different cultural background. → In order to prepare local people for the study, the overall research project should be introduced in good time. Give information about, and communicate the objectives of, the MARP study, methodologies, visions (and in as much detail as possible) to target groups: and do it early enough. Local people (not only representatives) should be involved right from the beginning of the conception of the study. Compensation could be provided to participants (local people) for hours spent for the study. In order to avoid cultural disturbances in the villages and provide for compliance with local norms and rules, researchers should be given cultural awareness training.

Key reference(s): Diagnostic participatif de la gestion des ressource naturelles sur le plateau Mahafaly Commune Rurale de Beheloka – Toliara, SuLaMa, 2011 • Summary MARP survey, SuLaMa, 2012 • Freudenberger, K. (1999). *Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) - A manual for CRS field workers and partners*. Baltimore, Maryland.
Contact person(s): Nadine Fritz-Vietta, University of Greifswald, Jahnstr. 16, 17487 Greifswald, nadine.fritz-vietta@uni-greifswald.de

left: Staff of Madagascar National Parks during a workshop on survey techniques for use in biodiversity monitoring programs. (Photo: Yedidya R. Ratovonamana)
right: Para-ecologist during a reptile survey at night holding a warty chameleon. (Photo: Joachim Nopper)

Participatory monitoring and evaluation of long-term changes in ecosystems

Madagascar

Establishing a knowledge base and communication platform in collaboration with para-ecologists for monitoring changes in ecosystems, to aid decision-making in forest management.

This approach strengthens knowledge about the response of biodiversity to environmental changes – namely land conversion, climate change induced impacts and climate-related extreme events, such as droughts and cyclones. Information generated can be used to inform regional authorities. They are then able to adapt management to current conditions, in order to better preserve biodiversity within the National Park. An important component of this approach is the integration of people from the local population as 'para-ecologists' who are trained in survey techniques for biodiversity monitoring. They directly observe changes in biodiversity, and share their knowledge with others in the area. The approach, thus, includes the sensitization of the local population to impacts of environmental change on biodiversity.

Under this approach, local assistants were trained in biodiversity monitoring techniques by researchers during their regular research activities. Part of the process comprised skills in species identification. Because the researchers had a limited period available for field work, training of these para-ecologists was a pre-requisite for implementation of long-term monitoring activities based on surveying at regular intervals. The surveys initiated by the researchers were plant phenology monitoring, regular capture, marking and recapture of *Galidictis grandidieri* (the giant striped mongoose) which is a flagship species in the Tsimanampesotse National Park, as well as reptile occurrence monitoring along transects. Monitoring procedures were established, and then continued by para-ecologists under the guidance of a Malagasy researcher who is familiar with ecological field work and acted as a 'scientific coordinator'. The task of the scientific coordinator was data control and storage, planning of monitoring activities, as well as communication between national authorities, ecologists and para-ecologists. All survey data are available for scientific purposes and can be used to inform Malagasy authorities, or can be directly demanded by Malagasy authorities.

A basic research camp for monitoring was established within the Tsimanampesotse National Park in collaboration with Madagascar National Parks and WWF Toliara with third party funding. Four para-ecologists, two cooks and a guard constitute the team. The camp is maintained by a manager who is responsible for maintenance of buildings and electric facilities as well as provision of food. Surveying equipment is stored at the base camp. Computers and other necessary equipment were provided under the SuLaMa project. There are two para-ecologists trained on flora and a further two on fauna. Survey sites for monitoring of animal diversity and plant phenology were established by plant and animal ecologists in cooperation with the para-ecologists. Infrastructure for data acquisition and storage was established. This included the installation of electrical facilities as well as the provisioning of field books and computers. Technicians received language courses and learned computer operation. Regular exchange between the research camp and the national park authority, MNP, was established through a permanently employed scientific coordinator. This exercise resulted in a first workshop on survey techniques, in which staff of Madagascar National Park learned from researchers and para-ecologists.

Location: Atsimo-Andrefana (South-West Madagascar), Beheloke
Approach area: 1 - 10 km^2
Type of approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: A_MAD005en
Related technology: none
Compiled by: Joachim Nopper, Animal Ecology and Conservation, Universität Hamburg, joachim.nopper@uni-hamburg.de,
Date: 11th April 2016

Problem, objectives and constraints

Problems:
Lack of knowledge about the changes in biodiversity within the national park; inadequate expertise in animal and plant identification; lack of knowledge about standardized sampling methods; data storage and dissemination not established.

Aims / Objectives:
Collect data on biodiversity to increase understanding of environmental change impacts. Use of this data to inform conservation managers. Involve the local population in this process to raise awareness and create ownership.

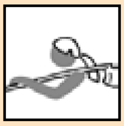
Constraints addressed

	Constraints	Treatments
Technical	No housing and facilities for para-ecologists, no infrastructure for data entry and storage, or for storage of equipment	Establishment of a research camp as the base for all monitoring activities; Establishment of a database for storage of survey data. Keeping of a copy by the scientific coordinator who is able to distribute the data to researchers.
Workload	Due to various reasons, surveys were occasionally cancelled.	Data quality of monitoring programs suffers if surveys are not conducted at regular intervals. To avoid the cancellation of surveys, two persons were trained in the same survey techniques, so that a replacement is available. Nevertheless, occasional cancellations could not be avoided.
Social / cultural / religious	Language barrier.	Employment of a French teacher.

Participation and decision making

Stakeholders / target groups


planners


Land users, individual


politicians / decision makers

Approach costs met by:

– International (German Ministry of Education and Research, BMBF)	100%
Total	**100%**

Annual budget for SLM component:
US$ 10,000-100,000

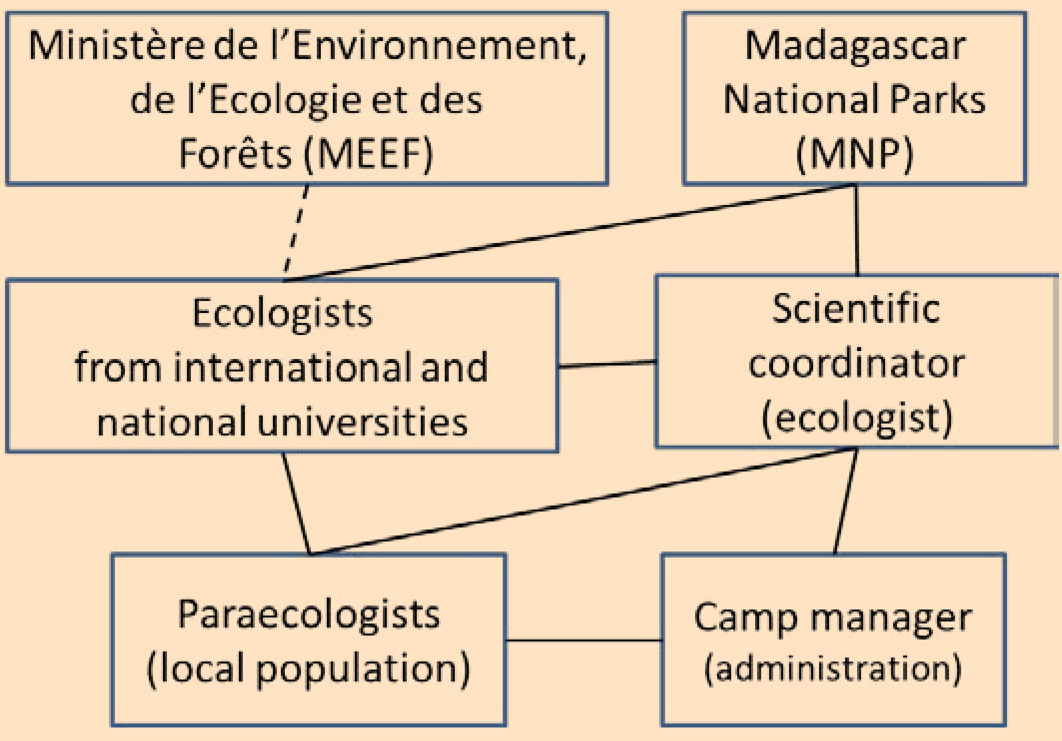
Decisions on choice of the Technology: By researchers.
Decisions on method of implementing the Technology: By researchers.
Approach designed by: Researchers.
Implementing bodies: Researchers, international (BMBF), national non-government (Madagascar National Parks (MNP), World Wild Fund (WWF)), government (*Ministère de l'Environnement, de l'Ecologie et des Forêts* (MEEF))

Land user involvement through para-ecologists

Phase	Involvement	Activities
Initiation/motivation	Payment/external support	Training, identification of places for monitoring activities
Planning	None	
Implementation	Payment/external support	Monitoring within the National Park, giving results of research to National Park staff
Monitoring/evaluation	None	
Research	None	

Differences between participation of men and women: Yes, moderate. Para-ecologists are all men. Camp staff are equally divided between women and men. No woman occupied a top position however.

Involvement of disadvantaged groups: No



Organogram: Key partners for a biodiversity monitoring programme in southwestern Madagascar. Collaborative research is focussed in and around Tsimanampesotse National Park. Ecologists train para-ecologists and develop long term monitoring programs. Scientific coordinator collects data and communicates results to MNP. Para-ecologists conduct surveys, a camp manager ensures research equipment is available and coordinates maintenance.

Technical support

Training / awareness raising: Local men who were trained in animal and plant identification and survey techniques. They became specialists in their area of work and due to regular surveys, better understand the effects of environmental changes on plant phenology and the occurrence and behaviour of animals. They share their knowledge in their villages, thus contributing to raising awareness about the environment.
Advisory service: The extension system is inadequate to ensure continuation of activities.

Research: Yes, great support by research. Topics covered include ecology and biodiversity conservation. Research was undertaken within the national park. Extension of research activities into non-protected areas were enabled through collaboration with the local communities. Mostly on-station research.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Paid in cash. Monthly salary for para-ecologists, as well as staff of research camp.
Input:

- Equipment: electrical facilities and research equipment (such as computers, GPS units, cameras, flagging, notebooks). Fully financed
- Infrastructure: cart for transport of equipment for research and camp maintenance. Fully financed
- Construction material: construction & maintenance of research camp. Fully financed

Credit: Credit was not available.
Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
Technical	Ad hoc observations. Data collection by para-ecologists was observed by researchers during training phase.
Control of data quality	Ad hoc observations by ecologists and scientific coordinator
Regular data collection	Regular by project staff.

Changes as result of monitoring and evaluation: There were no changes of the approach.

Impacts of the Approach

Improved sustainable land management: No; This approach is to evaluate long-term impacts of land conversions, gradual climate change and climate-related extremes (disasters) on biodiversity. Due to insufficient data because of the short time since implementation, impacts have not yet been assessed.
Adoption by other land users / projects: Yes, few; Community-based monitoring is on the rise in Madagascar.
Improved livelihoods / human well-being: Yes, little; Para-ecologist and associated staff of the research camp were continuously employed; a job opportunity that is rarely encountered within the study region. Awareness of the value of biodiversity has been raised.
Improved situation of disadvantaged groups: Yes, little; By providing employment for some local people.
Poverty alleviation: Yes, little; By providing employment for some local people.

Training, advisory service and research:

- Training effectiveness:
  Para-ecologists: excellent
  Para-ecologists from local villages were trained in standardized monitoring techniques and plant and animal identification. They are now able to collect data within a biodiversity monitoring program.
- Research contributing to the approach's effectiveness:
  Great support: Para-ecologists are supervised by researchers and receive updates on taxonomic issues. Scientific analyses of collected data are necessary to detect changes of monitored entities.

Land/water use rights: None of the above in the implementation of the approach. This approach depends on the general acceptance of the land owner to allow monitoring activities.
Long-term impact of subsidies: Long term financing of monitoring activities and especially para-ecologists needs to be assured in order to gain the necessary data to analyse biodiversity dynamics.

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Payments / subsidies: employment. Well-being and livelihoods improvement: regular salaries.
Sustainability of activities: No the land users can`t sustain the approach activities without support. Data collection by members of the local population is only valuable if data are subsequently quality-assured, analysed and evaluated. Thus without support from researchers this approach is of no value.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Collecting data and knowledge to support evidence-based decision-making for biodiversity conservation → Maintain and carry forward the knowledge base and communication platform by ensuring continued funding.	Monitoring activities depend on continuous funding. Funding was provided by SuLaMa/BMBF. Efforts for continuation of funding need to be undertaken throughout the project implementation period as well as after the project has terminated → The situation could be stabilized by mainstreaming monitoring activities in programs of in-country authorities, which is planned but has not yet been implemented.
By employing people from villages surrounding the national Park in regular research activities as well as biodiversity monitoring, knowledge about the dynamics of natural systems is experienced first-hand and can be transmitted to other members of the local communities. This can be seen as an informal knowledge hub from which communities learn more about the ecosystem they live in → Creating ownership might lead to more sustainable resource use practice.	

Contact person(s): Joachim Nopper, Animal Ecology and Conservation, Universität Hamburg, joachim.nopper@uni-hamburg.de • Yedidya R. Ratovonamana, Département de Biologie et Ecologie Végétale., Université d'Antananarivo, Madagascar, ryorch@yahoo.fr

left: Conservation Agriculture: hand-hoe dug basins with dry mulch (Photo: Maxon Simfukwe)
right: Oxen- ripped-lines with maize crop at vegetative stage (Photo: Maxon Simfukwe

Conservation Agriculture in a semi-arid area

Namibia - Lima nawa (Vambo/ Rukwangali)

Conservation agriculture using permanent water-harvesting planting basins, or rip-lines and fertilizer/manure application on low fertility dryland soils

Farmers in north-eastern Namibia practice shifting/semi-permanent subsistence cropping, concentrating on pearl millet cultivation. Here, conservation agriculture (CA) was promoted to sustain and improve production and to reduce conversion of woodland to crops. CA comprises the three principles of minimum soil disturbance, permanent soil cover, and rotation. CA was tested on small plots with volunteers trained by a local NGO. The technology was characterized here by: (i) Early (pre-rains) preparation of the land with two alternative techniques; either: a) basins with a defined spacing opened by a hand hoe, with composted manure added (biochar has also been tested), or b) rip-lines prepared with oxen in lines and with manure application within the rip lines; (ii) Mulching the soil with crop residues, branches or sunnhemp, specially grown for the purpose; (iii) Protection against grazing of crop and mulch by livestock; (iv) Intercropping with vegetables or legumes. (v) Weeding.
CA has been promoted for four seasons, and now trained farmers are transferring their knowledge to others. The technology was promoted to substantially improve the low yields of traditionally practiced agriculture by improving fertility and soil structure as well as better capturing runoff. It was also aimed at avoiding further expansion of croplands into dry woodlands on low fertility arenosols. Eventually it is hoped that the well-being of local subsistence cropping communities will be improved and outmigration reduced.
Knowledge about CA comes from Zambia, where it has been has been practiced successfully for many years by small-scale farmers. A local NGO was engaged by an international project (www.future-okavango.org) which searched for volunteer farmers in the Kavango area. The first CA planting took place in 2011/12. These pioneer farmers were backstopped regularly and the number of farmers trained increased. The NGO monitored crops with contact farmers. 45 more farmers showed interest and were then trained by the contact farmers. Training and backstopping continued until August 2015.
The natural environment is semi-arid. Rainfall is concentrated from November to March. Mean annual precipitation is 570 mm, and mean air temperature is 26.2°C in the hottest month (October) and 16.2°C in the coldest month (July). The landscape forms part of the extended Kalahari basin in central-southern Africa. Deep and extended sands restrict people to living in areas close to surface water. Villages are located along the Okavango on the elevated river terraces – where they produce crops. Here, sedimentation of fine-grained soils, the accumulation of calcium carbonates in the subsoil and the activity of termites have resulted in soils of medium fertility which could potentially ensure yields of 500 kg/ha of millet, if well managed, and assuming good rainfall. Due to the growing population and restricted land availability, cultivation patterns have changed from shifting to semi-permanent and expanded to the adjacent woodlands on the deep Kalahari sands. Here, rapid degradation of soil fertility has caused further expansion and reduced crop yields to very low levels (ca. 150 kg/ha on average). Livestock graze and browse vegetation on the floodplains and in the woodlands. Due to night-time kraaling of livestock, manure is available as fertilizer: thus sustained cropping can be supported. The importance of the woodlands for ecosystem services including timber and firewood, for thatching grass, medicinal plants and biodiversity means they must be conserved and this acts as a reason to support the search for alternative crop production systems such as CA.

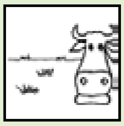
Location: Kavango East
Region: Mashare
Technology area: < 0.1 km^2
Conservation measure: structural, agronomic
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: developed externally / introduced through project, recent (<10 years ago)
Land use type: cropland: annual cropping
Climate: semi-arid, subtropics
WOCAT database reference: T_NAM001en
Related approach: none
Compiled by: Alexander Groengroeft, Universität Hamburg, 20146 Hamburg, Germany. alexander.groengroeft@ifb.uni-hamburg.de
Date: 2015, updated August 2016

THE FUTURE OKAVANGO

Classification

Land use problems: Low and very variable yields per ha; ongoing expansion of fields into less fertile woodlands due to nutrient depletion of originally fertile plots; years with dry spells (expert's point of view). Crop wilting and poor yields, opening new areas in search of better fields, cutting down trees, slashing and burning residues (land user's point of view).

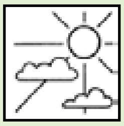
Land use

annual cropping: millet intercropped with legumes, rainfed

extensive grazing land rainfed

Climate

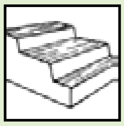
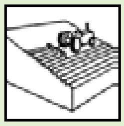


semi-arid, subtropics

Degradation

chemical soil deterioration: fertility decline and reduced organic matter content

Conservation measure

structural: basins and rip-lines

agronomic: soil surface treatment

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land user's initiative:
Experiments / research
Externally introduced: recent (<10 years ago)

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: soil management

Main technical functions:
- increase in nutrient availability (supply, recycling,…)
- increase in organic matter
- water harvesting / increase water supply (microbasins)
- increase / maintain water stored in soil

Secondary technical functions:

Environment

Natural Environment

Average annual rainfall (mm)

> 4000
3000-4000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Altitude (m a.s.l.)

> 4000
3000-4000
2500-3000
2000-2500
1500-2000
1000-1500
500-1000
100-500
<100

Landform

plateau / plains
ridges
mountain slopes
hill slopes
footslopes
valley floors

Slope (%)

flat
gentle
moderate
rolling
hilly
steep
very steep

Soil depth (cm)

0-20
20-50
50-80
80-120
>120

Growing season(s): 135 days (Nov to March)
Soil texture: coarse / light (sandy)
Soil fertility: very low
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: good

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: droughts / dry spells
Sensitive to climatic extremes: no experience yet
If sensitive, what modifications were made / are possible: dig basins 20cm deep (instead of 15cm); and extra water harvesting basins at 0.45m in-between the rows (instead of 0.9m). For the ox-ripped lines, use ripper wings to open a wider furrow to capture more water. General control/improvement of mulch layer

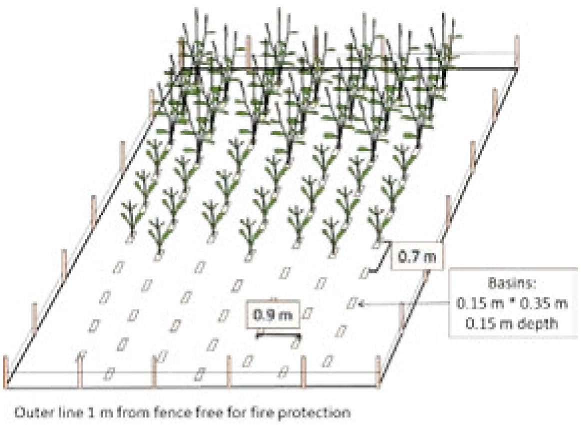
Human Environment

Cropland per household (ha)

■ (black)	<0.5
■ (grey)	0.5-1
□	1-2
□	2-5
□	5-15
□	15-50
□	50-100
□	100-500
□	500-1,000
□	1,000-10,000
□	>10,000

Land user: individual / household, Small scale land users, average land users, men and women.
Population density: 10-50 persons/km^2
Annual population growth: 1% - 2%
Land ownership: communal / village
Land use rights: communal (organised)
Water use rights: communal (organised) (parallel existence of state and communal laws)
Relative level of wealth: poor

Importance of off-farm income: 10-50% of all income: pensions & remittances, salaries, own business
Access to service and infrastructure: low: health, education, technical assistance, employment (e.g. off-farm), market, energy, financial services; moderate: roads & transport, drinking water and sanitation
Market orientation: subsistence (self-supply)
Mechanization: manual labour
Livestock grazing on cropland: no



Technical drawing

Scheme of CA field with basins
Within the fenced area, basins are dug per hand-hoe in lines with about 15 cm width, 35 cm length and 15 cm depth and in 70 cm distance. To keep the line and position, a rope with knots every 70 cm is used. Each basin is refilled with 2 cans of manure mixed with part of the soil material. Maize or pearl millet - two stages shown on the graph. (Maxon Simfukwe)

Implementation activities, inputs and costs

Establishment activities for hand basin system

1. Digging the planting basins (556 hours/ha)
2. Constructing fences against livestock (cattle & poultry). Fences can be constructed any time before field cultivation, typically in the dry season.

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	1104.00	100%
Construction material		
– wire for fencing (400m)	224.00	100%
– sticks & poles (collected and rarely purchased)	1114.00	100%
TOTAL	**2442.00**	**100%**

Maintenance/recurrent activities for hand basin system

1. Repairing fences and de-bushing of the fields (May - July)
2. Spreading of collected mulch cover (October - December and reinforced in February – March)
3. Cutting sunnhemp and applying as additional mulch (October - December)
4. Re-digging the planting basins (annually in August due to sandy soils; 556 hours/ha)
5. Collection and application of manure (September; 15 t/ha; usually own manure otherwise USD 0.92/50kg bag)
6. Sowing of main crops and sunnhemp and fertilizer application (November - December)
7. Intercropping with legumes like groundnuts and cowpeas normally two weeks after germination of cereals.
8. Weeding (mulching does not yet suppress weed to 100%)
9. Harvesting (April – May)

Animal-traction based CA farmers usually rip their field in October, which is directly followed by the application of manure

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	848.00	100%
Agricultural		
– fertilizer	159.00	100%
– compost/manure (300 bags)	276.00	100%
– seeds	22.00	100%
– mulch cover	0.00	100%
Construction material		
– wire and sticks	220.00	100%
TOTAL	**1525.00**	**100%**

Remarks:
CA was designed to require minimal financial investments; theoretically, everything apart from wire for the fences and inorganic fertilizer can be created or gathered by the household. This turns CA into a very labour intensive farming practice. The high US$ values above result from multiplying the (free) family labour invested in farming with the typical hourly wage rate of an external worker. The costs are based on labour needs of one year and 500 kg/ha of fertilizer.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ increased crop yield
+++ increased farm income

Production and socio-economic disadvantages

−− increased expenses on agricultural inputs
− increased labour constraints

Socio-cultural benefits

Socio-cultural disadvantages

− envy of neighboring farmers

Ecological benefits

+++ increased nutrient cycling recharge
++ increased soil moisture
++ reduced evaporation

Ecological benefits continued

++ improved soil cover
++ increased soil organic matter / below ground C
++ Increased soil biological activity

Off-site benefits

+++ reduced deforestation

Off-site disadvantages

−− nutrient depletion of surrounding areas

Contribution to human well-being / livelihoods

Improved and stabilized yields help rural families to adapt to modern lifestyles. However, the long-term contribution of CA to the well-being of the local farmers cannot be foreseen. The establishment of family-owned fenced areas for crop production is likely to have an influence on the social structure of the rural communities.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	investment in fences is regarded as an ongoing benefit for the future	not specified
Maintenance/recurrent	most costs can be met by the land user, few cash requirements	not specified

Acceptance/adoption: 0% of land user families have implemented the technology with external material support. SLM Technology has been applied through the interest and efforts of some smallholders. 100% of land user families have implemented the technology voluntarily. There is strong trend towards (growing) spontaneous adoption of the technology.

Concluding statements

Strengths and → how to sustain/improve

Timely land preparation → Don’t need to wait for the rain to start land preparation.

Permanent planting stations – nutrients are concentrated → Open same basin / rip-line for planting every season

Moisture retention → Basins/rip-lines with residue cover / no burning.

Intercropping of cereals (pearl millet / maize) and legumes (cowpeas, beans and groundnuts) encouraged → Combined with fertilization will result in a substantial improvement of soil fertility, which may encourage farmers to rotate between cereals and vegetables between years.

Precision / less wastage of inputs → By planting only in basins/ rip-lines and so is application of other amendments (manure / fertilizer) as recommended.

Saves labour over time → Able to start land preparation early at own pace before the rains start. Can even start after harvesting.

Can use less land compared to conventional system for the same harvest/yield → Keeping the same planting basins / rip-lines increases nutrient status of planted soil over time.

Weaknesses and → how to overcome

At the beginning it is labour intensive due to hard pan caused by years of ploughing → Because the basins/rip-lines are permanently maintained in CA, succeeding land preparation becomes easier. Also since land preparation starts before on-set of rains, one can spread labour by starting just after crop harvesting.

Need to agree with the local leadership to allow those doing CA to fence off their fields for protection from livestock → Fencing of fields in communal lands.

Weed management/pests → Application of more residues and weeding regularly in the first season; eventually reduces as more residues increase in the field and eventually suppresses the weeds.

Key reference(s): Groengroeft, A., et al. (2013) A method for yield assessment on rainfeld dryland agricultural fields. Biodiversity & Ecology 5:279 - 286. • Kowalski, B. et al. (2013) Mashare - The People. Biodiversity & Ecology 5:121-128. • Pröpper, M. et al. (2010) Causes and perspectives of land-cover change through expanding cultivation in Kavango. In Biodiversity in southern Africa. Volume 3: Implications for landuse and management, eds. M. T. Hoffman, U. Schmiedel and N. Jürgens. Göttingen & Windhoek: Klaus Hess Publishers. • Pröpper, M. et al. (2015) The Future Okavango – Findings, Scenarios and Recommendations for Action. Research Project Final Synthesis Report 2010-2015, 190. Windhoek: University of Hamburg

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left: Stubble cultivation under minimum tillage (KULUNDA)
right: Test plots of the three cropping systems studied: conventional, adapted and modern in Poluyamki, . Between the test plots, the protective strips can be seen. (Photo: Patrick Illiger)

Minimum Tillage

Russian Federation

Minimum tillage is a one-pass operation combined with sowing, using a classic Russian seeder modified for seedbed preparation and soil mixing. It can include shallow stubble cultivation after harvesting.

Minimum tillage is a key element of the "adapted Soviet cropping system", which aims at more sustainable land use but based on predominantly local technologies. For successful implementation of minimum tillage, adaption of the whole cropping system is required, including crop rotation. Rotation includes a succession of cereal crops (e.g. spring wheat), legumes (peas), and oil seed crops. Stubble cultivation in autumn is best performed with the "Catros" compact disc harrow for a quick, shallow operation. Seedbed preparation is carried out using a classic Russian seeder modified with wing shares for shallow seedbed preparation including soil mixing. In general, the performance of this drill is very close to that of a cultivator.

Minimizing tillage, saves time and fuel, and also helps to reduce evaporation, as well as protecting the soil against erosion. Shallow tillage with disc harrows after harvest ensures better stubble mixing and stimulates the germination of weed seeds. The adapted seeder, SZS 2.1, works with wing shares that open the soil and place the seed. Thus traditional deep tillage operations for the preparation of the seedbed can are omitted: that helps to reduce costs. With respect to crop protection, the first and most important element is to implement a full crop rotation. To control late germinating weeds and seeds of the previous crop, a disc harrow is used for shallow cultivation – this can be supplemented by the application of a non-selective herbicide if there is germination - to avoid the risk of flowering before the hard frost sets in. Fertilization becomes more important, because of the decreased mineralization rate under minimized soil tillage, especially at the beginning of the conversion of the cropping system.

The Technology including crop rotation was tested in the field in 4 test plots with 4 repetitions at the test site in Poluyamki. Results showed that the intensity of soil tillage and seeding methods used had a great influence on crop establishment and expected yields. It was demonstrated that minimizing tillage leads to higher water use efficiency and highest yields. Positive effects were also observed regarding soil structure and soil fertility already after 3 years. Minimized soil disturbance led to higher aggregate stability, which leads to a lower risk of wind erosion, increased soil organic carbon storage and soil fertility as well as available soil water content. The adapted Soviet system is more profitable, due to higher gross margins.

The test site in Poluyamki is located in the dry steppe of the border region next to Kazakhstan, where, due to the climatic conditions, no natural afforestation occurs, and the planted windbreaks don't grow vigorously due to the prevailing aridity. The annual precipitation is under 300 mm a year. Probably the greatest climatic influence factor is the precipitation - in terms of quantity and space/ time distribution and, due to high summer temperatures, the high rates of evapotranspiration. The total yearly precipitation rate is the primary yield-limiting factor in all steppe regions. The ratio between precipitation and evaporation is negative. In the late weeks of spring, prolonged droughts must be expected in 5-year cycles, limiting germination and crop establishment. The soils are classed among those of cool-tempered grasslands. Due to their physical and chemical characteristics, these soils (Chernozems and Kastanozems) have high agronomic potential.

Location: Russian Federation/Altai Krai
Region: Mikhaylovski district (Pavlovski district, Mamontovski district)
Technology area: 0.13 km^2
Conservation measure: agronomic, management
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: developed through experiments / research, recent (<10 years ago)
Land use type: cropland: annual cropping
Climate: semi-arid, temperate
WOCAT database reference: T_RUS027en
Related approach: A_RUS004en (Vocational Training), A_RUS003en (Field days)
Compiled by: Peter Liebelt, Martin-Luther-University, Halle-Wittenberg, peter.liebelt@geo.uni-halle.de
Date: 23th June 2016, updated August 2016

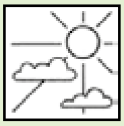
Classification

Land use problems: The decrease of soil organic carbon content in the soils and loss of topsoil depth has led to a decrease in soil fertility. Additionally, the negative soil water balance due to the high summer temperatures and evaporation, and the high spatial and temporal variability of precipitation, is a serious problem relating to the lack of soil water (expert's point of view). The land users who were involved in the studies and implemented the new farming practices have a similar opinion. But there are still a lot of farmers that underestimate the ecological risks of soil degradation resulting from conventional/ traditional soil management (land user's point of view).

Land use

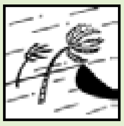
annual cropping rainfed

Climate



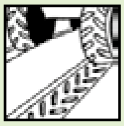
semi-arid

Degradation



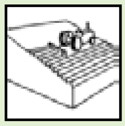
soil erosion by wind: loss of topsoil, offsite degradation

chemical soil deterioration: fertility decline and reduced organic matter content

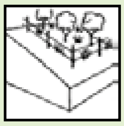


physical soil deterioration: compaction

Conservation measure



agronomic: soil surface treatment, improved organic matter/ soil fertility and vegetation/ soil cover



management: change of management/ intensity level

Stage of intervention

- ■ Prevention
- ■ Mitigation / Reduction
- ▒ Rehabilitation

Origin

- ▒ Land user's initiative: recent (<10 years ago)
- ■ Experiments / research: recent (<10 years ago)
- □ Externally introduced

Level of technical knowledge

- ■ Agricultural advisor
- ■ Land user

Main causes of land degradation:
Direct causes - Human induced: soil management, crop management (annual, perennial, tree/shrub)
Direct causes - Natural: wind storms / dust storms, droughts

Main technical functions:
- improvement of topsoil structure (compaction)
- increase in organic matter
- increase of infiltration
- increase / maintain water stored in soil
- sediment retention / trapping, sediment harvesting

Secondary technical functions:
- control of raindrop splash
- control of dispersed runoff: impede / retard
- control of concentrated runoff: impede / retard
- improvement of surface structure (crusting, sealing)
- improvement of subsoil structure (hardpan)
- increase in nutrient availability (supply, recycling,…)
- reduction in wind speed
- increase of biomass (quantity)

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- □ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- ■ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- □ 500-1000
- ■ 100-500
- □ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- ■ flat
- □ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- □ 0-20
- ■ 20-50
- ▒ 50-80
- □ 80-120
- □ >120

Growing season(s): 110 days (May-October)
Soil texture: medium (loam)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: high
Ground water table: 5 - 50 m
Biodiversity: low

Tolerant of climatic extremes: temperature increase, seasonal rainfall decrease and droughts, heavy rainfall events (intensities and amount), wind storms/ dust storms, droughts/ dry spells
Sensitive to climatic extremes: seasonal rainfall increase, decreasing length of growing period
If sensitive, what modifications were made / are possible: The minimization of soil tillage intensity helps to reduce the water evapotranspiration rate and thus leads to a higher soil water content. The stubble left in the fields slows down the wind, and this protects the soil against erosion, and reduces evapotranspiration.

Human Environment

Cropland per household (ha)

☐	<0.5
☐	0.5-1
☐	1-2
☐	2-5
☐	5-15
☐	15-50
☐	50-100
☐	100-500
☐	500-1,000
■	1,000-10,000
☐	>10,000

Land user: employee (company, government), large scale land users, Leaders / privileged, mainly men
Population density: 10-50 persons/km^2
Annual population growth: negative
Land ownership: state, individual, not titled
Land use rights: leased
Water use rights: open access (unorganised) (state: 45% The data refer to the Altai Krai)
Relative level of wealth: very rich to average

Importance of off-farm income: less than 10% of all income
Access to service and infrastructure: moderate: employment (eg off-farm), market, roads & transport, financial services; high: health, education, technical assistance, energy, drinking water and sanitation
Market orientation: commercial / market
Mechanization: mechanised

Technical drawing

Soviet Seeder SZS 2.1 with wing shares for shallow soil mixing and seed bed preparation. (Lars-Christian Grunwald)

Implementation activities, inputs and costs

Establishment activities

1. Tractor (MTS1221)
2. Tractor (Kirovets K701)
3. Harvester (Don 1500)
4. Disc harrow (Catros 6001)
5. Seeder (SZS 2.1)
6. Field sprayer (UX 5200)

*Depends on which machines need to be purchased

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Equipment/ machines*		
TOTAL		

Maintenance/recurrent activities

1. Stubble cultivation
2. Seeding
3. Seeding (extension)
4. Fertilizer application
5. Pest management
6. Pest management (extension)
7. Harvest

The costs refer to 1ha land of the test field / site in Poluyamki.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	4.34	
Equipment		
– machine use	37.40	
– fuel	47.34	
Agriculture		
– seeds	25.30	
– fertilizer	30.83	
– pesticides	9.42	
TOTAL	**154.63**	**100 %**

Remarks:
The highest cost factors of minimum tillage are equipment, fuel, fertilizer and seeds. Compared to the conventional deep ploughing often without fertilizer application, fertilizer and pesticides are the main additional cost factors.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
++ increased farm income	−− increased use of herbicide applications
+ reduced expenses on agricultural inputs	− increased expenses on agricultural inputs

Socio-cultural benefits	Socio-cultural disadvantages
++ improved conservation / erosion knowledge	

Ecological benefits	Ecological disadvantages
++ reduced wind velocity	−− increased use of herbicide application
++ improved soil cover	
+ increased soil moisture	
+ reduced evaporation	
+ reduced surface runoff	
+ increased nutrient cycling recharge	
+ increased soil organic matter / below ground C	
+ reduced emission of carbon and greenhouse gases	
+ reduced soil loss	
+ reduced soil compaction	
+ increased beneficial species	

Off-site benefits	Off-site disadvantages
+ increased water availability	
+ reduced wind transported sediments	
+ reduced damage on neighbours fields	

Contribution to human well-being/livelihoods

++ Technology makes a contribution to the long-term productivity of the soil – the most important factors in the rural areas of the Kulunda region. Furthermore, it leads to an increase in efficiency and to an improvement of the economic situation of farms, which might lead to a decrease in out-migration of the youth.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	neutral / balanced	positive
Maintenance/recurrent	slightly positive	positive

Acceptance/adoption: 100% of land user families have implemented the technology voluntarily. The 3 farms/ sites where minimum tillage was tested were already interested in conservation technologies and were able to invest in new machinery, which is not representative of the whole Kulunda region. There is a moderate trend towards spontaneous adoption, but this trend depends on different natural and socioeconomic factors, like precipitation or the economic situation and financial power of the farmers.

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Increase of soil aggregate stability and improved soil structure thus better erosion control and protection of soil organic matter will improve soil fertility and water holding capacity → Enough time to see the effect.	Need for comprehensive system knowledge and risk of significant crop losses in case of incorrect implementation → Knowledge transfer, Capacity building and extension services, State support (subsidies for new technologies)
Minimization of evaporation losses through the mulch layer → make sure that the soil is covered as much and long as possible.	Application of chemical herbicides leads to higher costs and possible ecological risks → Selective spraying using the “Amaspot” system that is based on infrared detection of weeds.
Protection of soil organisms thus ensuring natural soil forming processes. → Enough time to see the effect.	Higher requirements for fertilizers, especially at the beginning, due to lower mineralization rates and less nutrient availability compared to conventional cultivation → Higher fertilizer application in the first years after conversion.
Lower input costs (materials, fuel, labour, time) and quicker field operations. → Enough time to attain the economic advantages.	Challenging straw management that leads to higher risk of fungal infestation and poorer field crop emergence → Good straw management: effective straw chopping and spreading as well as stubble cultivation for an optimal straw/ soil ratio.
A great advantage of the tested ‘minimum tillage’ in contrast to ‘no till‘ is that the former needs no new machinery because of the use and adaptation of old Soviet machinery.	

Contact person(s): Peter Liebelt, Martin-Luther-University, Halle-Wittenberg, peter.liebelt@geo.uni-halle.de

left: Poster presentation of the project findings by 'Partner' Company at the field day in Poluyamki to explain the test plots arrangement and the investigated key technologies (minimum-till, no-till). (Photo: Peter Liebelt)
right: Discussion about the presented project findings with different local stakeholder (politicians, university lectures, advisers and farmer). (Photo: Peter Liebelt)

Field days

Russian Federation - Полевой семинар

Field days are events for regional stakeholders, mainly farmers in the study area, to discuss their demands regarding scientific help, and to be informed about the activities and results of new methods and technologies for conservation agriculture.

The approach aimed at raising awareness, encouraging exchange and communication for new sustainable land management (SLM) technologies including no-till and minimum till. The main goal - implementation of improved SLM technologies – was intended to be achieved through capacity building and strengthening of the acceptance of new technologies Field days, organized at a partner farm/ study site in Poluyamki (Mikhailovski Rayon), were a suitable framework for the achievement of this goal. Another objective of the field day is cooperation and networking between farmers, scientists, representatives of the regional politics and administration, and commercial companies. This stimulates the exchange of knowledge and the dissemination of new information about SLM - which is very important for the successful implementation and evolution of the technology.

For effective presentation of the minimum and no-till cropping systems to the public, and to give everyone present at the field day the opportunity to inform themselves about conservation measures, an information point was set up by the project. For spread of information about research activities, results and recommendations, posters were presented - and leaflets and brochures were handed out. In this way it was possible to promote knowledge transfer from the scientists to the farmers, and to receive feedback.

Furthermore, interdisciplinary and transdisciplinary knowledge exchange and discussion was initiated about the results and recommendations, which were based on the presentations given in the community centre. Due to the participation of many important local stakeholder groups, the field day was a suitable platform to contribute to network-building. Also, among the participants were private companies working in the agrarian sector. The cooperation partner of the research project, the Amazone company, also made presentations. In the study site the new tillage systems are already working. Furthermore the test farm unit in Poluyamki has also started to implement no-till and minimum tillage systems on fields outside the test farm, on farmer's fields that do not belong to the project's research sites and are not under the control of the project staff.

Farmers are the stakeholders of primary importance, since it is hoped they will take up and implement the conservation technologies. Therefore most participants during the field day were farmers. Those invited are interested in new technologies and have the necessary financial power to invest in new technologies. The chances of successful implementation in their farms are very good. Most of these farms already have experience in conservation technologies. In the investigation area, about 20-30% of land is already cropped/ cultivated under some form of conservation soil tillage.

Location: Altai Krai, Mikhaylovski district / rayon
Approach area: 0.13 km2
Type of approach: project/programme based. Field days are an accepted approach in this region to share new knowledge and implement innovations
Focus: mainly on conservation
WOCAT database reference: A_RUS003en
Related technologyes: T_RUS027en (Minimum Tillage), T_RUS028en (No Till)
Compiled by: Peter Liebelt, Martin-Luther-University Halle-Wittenberg, Germany, peter.liebelt@geo.uni-halle.de
Date: July 19th 2016, updated August 2016

Problem, objectives and constraints

Problems:
Low agricultural production and limited economic efficiency of conventional/ traditional farming systems - Lack of soil water and decrease of soil fertility under conventional/ traditional farming systems - Lack of technical knowledge to implement modern, adapted, technologies for cropping, and to cope with more extreme events such as prolonged drought.

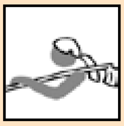
Aims / Objectives:
Improvement of technology adoption through: Awareness raising, knowledge exchange and transfer, capacity building

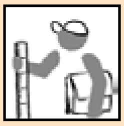
Constraints addressed

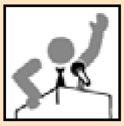
	Constraints	Treatments
Technical	In Russia conventional / traditional cultivation still prevails. although market for no-till technologies is fully developed and functional. Various machinery companies either have branches or production units in Russia.	More events where experience and results of min- and no-till can be shared and discussed.
Social / cultural / religious	Historically-caused low levels of trust among land users and other local stakeholder groups like education institutions or consulting services, among others, limits the adoption of “good farming practices”.	The field days and exchange of practice – oriented knowledge increased the confidence of farmers. This constraint can be addressed by specifically targeted policies, e.g. provision of grants or credit for the establishment of producer groups.
Institutional	Unfavourable framework conditions and low capacity of the administration to monitor the state of land and to enforce the soil protection law which would oblige land users to adopt conservation measures.	The approach did not address this factor.
Financial	High cost of new minimum and no-till machinery and difficult access to credits. Budget limitations are proportionately greater with smaller farms (highly variable yields reduce farm profitability, limited access to external funds)	Subsidized interest rates for machinery. In 2015 machinery for no-till tillage was not subsidized. Demonstrate that environmentally friendly innovative farming technologies are profitable and worthwhile to invest in.
Legal / land use and / water rights	Unclear land use rights. High share of rented land. Missing incentives to stimulate land users to adopt conservation practices. Secure land use rights motivates to more conscious care for the land and stimulates farmers to adopt better practices.	To make the best of private ownership, land users need to get a better concept of farming as a business. Strengthen the role of the ‘state redistribution of funding’ system (between different branches of the economy).

Participation and decision making

Stakeholders / target groups


land users, individual, groups


SLM specialists / agricultural advisors


politicians / decision makers

Approach costs met by:

– International (German Ministry of Education and Research, BMBF)	50%
– Private sector (AMAZONE Company for land use technology)	50%
Total	**100%**

Annual budget for SLM component: approximately US$ 10.000,00

Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology: Project staff: German and Russian scientists and SLM specialists
Approach designed by: Staff member of the project: German and Russian scientists, national specialists
Implementing bodies: German and Russian scientists of the project, local government (district Altai Krai), local community / land users

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	interactive	Experimental plots, demonstration plots and field days were held on land users farms
Planning	interactive	
Implementation	interactive	
Monitoring/evaluation	interactive	
Research	passive	

Differences between participation of men and women: No
Involvement of disadvantaged groups: No. farmers with necessary financial power to were mainly involved

Organogram:
The Field Day brings different stakeholder groups together and promotes new technologies and thus the implementation of conservation land use practices. This is through knowledge and exchange on resource-saving technologies. (Peter Liebelt)

Technical support

Training / awareness raising: Training provided for land user, field staff/agricultural advisors. Training was demonstration areas, public meetings, site and farmer-to-farmer visits. Training focused on competitiveness of agricultural enterprises, ecologically and economically effective farm management through introducing modern tillage systems, personnel management and monitoring systems.
Advisory service:
Name: Field days for demonstration and exchange
Key elements:
1. The field seminar was a suitable platform for knowledge exchange on agricultural production in the Kulunda steppe.
2. Capacity building: On-field demonstration as well as poster and presentations of project results and recommendations. Discussions in the field as well as in the lecture room allowed to address individual stakeholder questions and to suggest solutions.
Research: Research gave moderate support. Topics covered include technology, economics / marketing, ecology, sociology..

External material support / subsidies

Contribution per area (state/private sector): Yes. by the agricultural company 'AMAZONE'
Labour: Voluntary.
Input:
- Equipment (machinery, tools, etc). partly financed
- Agricultural (seeds, fertilizers, etc). partly financed

Credit: Credit was not available

Monitoring and evaluation

Monitored aspects	Methods and indicators
socio-cultural	Ad hoc observations: attitude
management of approach	Ad hoc observations by project staff
no. of land users involved	Ad hoc observations by project staff
bio-physical	Regular observations and measurement by project staff and land users of seed germination, crop and weed development, physical and chemical soil parameters as well as soil water.
technical	Regular observations and measurement by project staff and land users of functioning of the soil conserving technologies, seed and pesticide placement accuracy, fuel consumption, yield
economic / production	Regular measurements by project staff: input costs (labour seed, fertilizer, pesticide yield, profit margin

Changes as result of monitoring and evaluation:
There were no changes in the approach.

Impacts of the Approach

Improved sustainable land management: Yes, greatly. The field day allowed the transfer of project-based results on the subject of conservation agriculture to the local farmers and other regional actors and promotes the implementation of new soil conserving methods and strategies in the research area by the farmers.
Adoption by other land users / projects: Yes, some. The field days motivated the farmers and land use specialists to implement the conservation technologies. There is no information about the number of farmers who implement as a result of the field days.
Improved livelihoods / human well-being: Yes, little; By implementing the new conservation technologies the sustainability of farming systems in both the ecological and the economic sense increases.
Improved situation of disadvantaged groups: No; The implementation of the technology is not primarily aimed at these issues.
Poverty alleviation: Yes, little; The implementation of the minimum till and no till technologies protect the soil as an important living and economic basis.
Training, advisory service and research:

- Training effectiveness
  Land users: excellent
  Agricultural advisor / trainers, SLM specialists, politicians / decision makers: good
  The Field Day is primarily aimed at farmers. To involve the other mentioned actors different approaches for implementation were carried out, such as vocational training.
- Advisory service effectiveness:
  Land users: excellent
  The field day was a very effective measure especially for advising farmers, but also for the other stakeholders that participated including technicians and politicians.
- Research contributing to the approach´s effectiveness:
  Moderate support by research. Research results of tested SLM technologies help in evidence-based decision-making.

Land/water use rights: Land ownership hinders farmers for several reasons. There are still some legislative and administrative weaknesses that limit the full execution of the ownership rights (non-defined borders, lacking cadastral registration of some plots, missing owners, etc.). Furthermore, around half of the land utilized in Altai Krai is owned by the state (of that around 2 million hectares are administered by the Redistribution Fund). Another aspect is the capacity of the state monitoring agency (State Veterinary and Phytosanitary Controls) to control the compliance of the rules provided the land use conditions are stricter. The approach did not at all reduce the land/water use rights problem.
Long-term impact of subsidies: Moderate positive long-term impact. Currently, there is not an instrument that would directly influence the adoption of the conservation practices. There are several options for the government to implement tools that would influence farmers´ decisions on the land management practices.

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Increased profit(ability), higher profit margins improve cost-benefit ratio. Production: To minimize fluctuations in yield. Reduced workload: important especially for large farm sizes.
Sustainability of activities: Yes the land users can sustain the approach activities without support.

Strengths and → how to sustain/improve	**Weaknesses and → how to overcome**
Opportunity for farmers to get information about new agricultural machinery and other products for implementing new conservation farming system → More intensive and profound consultation by agricultural companies regarding new conservation technologies.	Great organizational effort required → More external support of field days for farmers.
Exchange of experience in sustainable land management between farmers → More participating farmers and continuous exchange not only between those during the field days.	Because of the high number of participants and the time limit field days are not well suited for coaching of individual farmers → Intensification of extension services. Initiation of additional events for advising.
Land user, specialists and advisers all get to know about new technical findings and basic research → **R**egular meetings between the stakeholders. Inclusion of knowledgeable and successful farmers will increase the acceptance of the results presented.	Reconciliation of basic research and applied research → Intensified cooperation between researchers and other stakeholders - including agricultural companies.
Participation of land users allows farmer-to-farmer learning → Inclusion of different stakeholders for broad knowledge transfer. Large number of visitors helps to disseminate knowledge.	Limited duration of the project → By enhancing continuity of measures that are independent of the project. Strategy to initiate and promote the engagement of local partners such as the agricultural university or farmer associations / groups.
Network building - strengthening and extension of the stakeholder platform. This platform includes different stakeholder spheres: extension service, land users, those in education, scientists, other support systems → By inviting various stakeholder groups and by creating opportunities for communication between participants.	

Contact person(s): Peter Liebelt, Martin-Luther-University Halle-Wittenberg, Germany, peter.liebelt@geo.uni-halle.de

left: Training seminar and discussion on the topic of more effective crop farming (Photo: Peter Liebelt)
right: Interview during the training session in the Vocational Training Center concerning the contents of the event and the aim and benefit of vocational training (Photo: Peter Liebelt)

Vocational Training

Russian Federation - Профессиональное обучение

Regular in-service training of land use specialists and farm managers in the fields of sustainable land use management, and monitoring in the agrarian sector.

By, as well as improved linkages of the agricultural consulting systems with universities and vocational training facilities,

Through targeted improved knowledge transfer, the Vocational Training Center is strengthening links between the agricultural consulting/ advisory systems, universities and vocational training facilities. The aim is to enhance capacity building and knowledge transfer for a better consultation / advisory system, especially. This concerns alternative conservation measures and SLM in rural areas. The centre and members of the different sub-projects of the KULUNDA project gave lectures covering up-to-date research results and on various topics, including SLM technologies (no-till and minimum tillage). Socio-economic and ecological impact was covered, as well as environmental monitoring. This took place at the 'Barnaul Institute for Qualification in Agriculture'. These lectures are embedded into an existing training programme for young professionals within the agronomic service and extension service/ advisory service as well as heads of agricultural enterprises.

It is also planned to present project results on the topic of sustainable land management in the State Agrarian University in Barnaul, which is the main training centre for future agronomists. This presentation takes different forms – for example through poster presentations or conferences. The implementation courses material/ modules are partially running (for lectures at the Barnaul Institute for Qualification in Agriculture) or are under preparation. Furthermore, there is a plan to cooperate with the Altai State University to organise a seminar on the topic entitled "Laboratory analysis to investigate soil conditions". Thus it helps to implement new methods of environmental monitoring into the current teaching program.

More recently, the project's partner, the German company Amazone, has started an initiative of vocational training for young people in the region: these students are being given the opportunity to enhance their knowledge at the company's production site in Samara and to learn about technical aspects of the two SLM technologies, namely no-till and minimum till.

The measures are aimed at different stakeholder groups within the Altai Krai identified in the AKIS-Network (Agricultural Knowledge and Information System). The greatest importance is attached to the stakeholders of extension service and agricultural producers/ heads of agricultural enterprises because of the high level of dependency on the successful implementation of the SLM technologies on their knowledge and support. The managers who participated in advanced trainings are mainly from economically strong agricultural enterprises.

Location: Altai Krai, Mikhaylovski district
Approach area: 80.000 km^2
Type of approach: traditional/ indigenous
Focus: mainly on conservation
WOCAT database reference: A_RUS004en
Related technologies: T_RUS027en (Minimum Tillage), T_RUS028en (No-Till)
Compiled by: Peter Liebelt,
Martin-Luther-University Halle-Wittenberg, Germany, peter.liebelt@geo.uni-halle.de
Date: July 26th 2016, updated August 2016

Problem, objectives and constraints

Problems:
There is a lack of knowledge on current scientific findings regarding innovative agronomic methods like minimum and no-till and a lack of awareness concerning the importance of the conservation technologies for economic and ecological sustainable farming strategies. A big problem is that the system for advising farmers is not sufficient, although there is a state institution for this purpose. There is a lack of awareness about the importance of vocational training, and lack of international, scientifically-based expertise in the regional institution conducting vocational training.

Aims / Objectives:
Improvement of technology adoption through: Capacity building, training and knowledge transfer. Awareness raising.

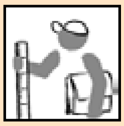
Constraints addressed

	Constraints	Treatments
Technical	In Russia conventional/ traditional cultivation still prevails, although market for no-till technologies is fully developed and functional. Various machinery companies either have branches or production units in Russia.	
Social / cultural / religious	Insufficient acceptance by land users of new and externally developed methods. Historically-caused low levels of trust among farmers/ land users that, amongst others, limits the transfer of 'good farming practices'.	Awareness raising, training and knowledge sharing for environmental problems due to non-adapted farming systems. Specifically targeted policies (e.g. provision of grants or credit for the establishment of producer groups) and awareness raising.
Institutional	Unfavourable framework conditions and low capacity of the administration to monitor the state of land and to enforce the soil protection law which would oblige land users to adopt conservation measures.	The approach did not address this factor.
Financial	High cost of new minimum and no-till machinery and difficult access to credits. Budget limitations are proportionately greater with smaller farms (highly variable yields reduce farm profitability, limited access to external funds)	In the training modules specialists were trained on how to improve the profitability, to work economically and rationally by implementing alternative conservation measures and SLM as well as by efficient personnel management in the agricultural enterprises.
Legal / land use and / water rights	Unclear land use rights. High share of rented land. Missing incentives to stimulate land users to adopt conservation practices. Secure land use rights motivates to more conscious care for the land and stimulates farmers to adopt better practices.	Discussion of the options to strengthen the role of 'State Redistribution of Funding' in favour of funding land protection.

Participation and decision making

Stakeholders / target groups

land users, individual; agricultural producers and heads of agricultural enterprises



SLM specialists/ agricultural advisors/ extension agents

Approach costs met by:

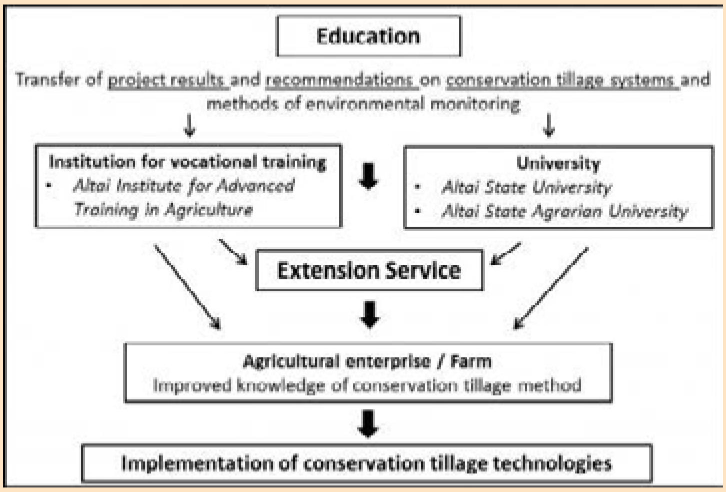
– International (German Ministry of Education and Research, BMBF)	100%
Total	**100%**

Annual budget for SLM component: approximately US$ 10.000,00

Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users
Decisions on method of implementing the Technology: German and Russian scientists and SLM specialists
Approach designed by: German and Russian scientists, national specialists
Implementing bodies: German and Russian scientists of the project, government (belongs to the Ministry of Agriculture), local government (district, county, municipality, village, etc.)

Land user involvement		
Phase	**Involvement**	**Activities**
Initiation/motivation	Interactive	The training modules are embedded in the existing training programme of the vocational training centre in Barnaul.
Planning	None	Project-internal in consultation with the head of vocational training centre.
Implementation	Interactive	Interactive lecturing and training on latest findings and recommendations of the project. Participants are actively involved by question and answer sessions, as well as by intensive discussions.
Monitoring/evaluation	Interactive	Evaluation after the event through project internal discussions as well as interviews with regional stakeholder.
Research	None	

Differences between participation of men and women: Yes, moderate. There are more men working in the area of crop production than women: more men participated.
Involvement of disadvantaged groups: No.



Organogram:
The chart is intended to show the importance of the vocational training by the 'Institute for advanced training in agriculture' concerning knowledge transfer and capacity building. Knowledge transfer takes place either directly or indirectly through the advisory service to the farmers. Due to the capacity building measures and resulting better knowledge of the farmers about conservation technologies this approach will better enable them to implement conservation technologies. (Peter Liebelt).

Technical support

Training / awareness raising: Training focused on competitiveness of agricultural enterprises, ecologically and economically effective farm management through the use of resource-conserving crop production, costs of introducing modern tillage systems, personnel management, and monitoring systems.
Advisory service:
Name: Vocational training for land use specialists / advisers, land managers and land users
Key elements:
1. Knowledge / exchange; 2. Capacity building; 3. Training of trainers.
There is already mainly a governmental advisory structure. However, international expertise is absent, and there is a demand from land users for consultation. The extension system is quite adequate to ensure continuation of activities
Research: No research.

External material support / subsidies

Contribution per area (state/private sector): Yes. The Altai Institute for Advanced Training in Agriculture, which is publicly funded, provided staff, an auditorium and has promoted the event.
Labour:
Input: Preparation of training material was fully financed
Credit: Credit was not available
Support to local institutions: Yes. Expenditures directly related to the vocational training (travel expenses, accommodation, cost of information materials, cost of food) were taken in charge by the project.

Monitoring and evaluation

Monitored aspects	Methods and indicators
technical	Ad hoc observations by project staff and government: technical parameters Ad hoc measurements by target groups
economic / production	Ad hoc observations and measurements by project staff and government: economic parameters (profit margins and others).
management of Approach	Ad hoc observations by project staff and government: management parameters

Changes as result of monitoring and evaluation:
There were no changes in the approach. There were no changes in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, great. The approach vocational training helps to improve knowledge transfer and the quality of advisory service and to inform the land user directly, who in turn will be the ones to implement new conservation technologies.
Adoption by other land users / projects: Yes, some
Improved livelihoods / human well-being: Yes, little; by implementing the no/ minimum tillage the sustainability of farming systems in both the ecological and the economic sense increases. The technologies help to protect soil as the production base for farming.
Improved situation of disadvantaged groups: No; The implementation of the technology is not primarily aimed at these issues.
Poverty alleviation: Yes, little.
Training, advisory service and research:

- Training effectiveness
  Agricultural advisor / trainer, SLM specialists: excellent
  Agricultural producers and heads of agricultural enterprises politicians: poor
  The training was suitable for transfer of knowledge to the specialists and consultants
- Advisory service effectiveness:
  Land users: good
  Technicians / conservation specialists, teachers: excellent
  Field days on conservation technologies are preferable for farmers/ land users due to higher practical orientation.
- Research contributing to the approach´s effectiveness:
  Research is very important due to the fact that mainly own research results were presented and discussed in the trainings.

Land/water use rights: Land ownership hinders farmers for several reasons. There are still some legislative and administrative weaknesses that limit the full execution of the ownership rights (non-defined borders, lacking cadastral registration of some plots, missing owners, etc.). Furthermore, around half of the land utilized in Altai Krai is owned by the state (of that around 2 milion hectares are administered by the Redistribution Fund). Another aspect is the capacity of the state monitoring agency (State Veterinary and Phytosanitary Controls) to control the compliance of the rules provided the land use conditions are stricter. The approach did not at all reduce the land/water use rights problem.
Long-term impact of subsidies: Moderate positive long-term impact. Currently, there is not an instrument that would directly influence the adoption of the conservation practices. There are several options for the government to implement tools that would influence farmers´ decisions on the land management practices.

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production: secure yield through a higher sustainability. Payments/ subsidies. Reduced workload especially for large-size farms. Increased profit(ability). Affiliation with the KULUNDA project.
Sustainability of activities: Yes, the Altai Institute of vocational training can continue with the help of learning modules and various information materials that were prepared under the project.

Strengths and → how to sustain/improve	**Weaknesses and → how to overcome**
To have a platform for discussion and knowledge exchange with different national stakeholder groups as well as international scientists → Regular meetings for knowledge exchange.	For land user it takes a lot of effort like high costs and time to visit the event in the capital Barnaul.
To get information about the latest international 'trends' in agriculture that aim at economically effective, resource-saving and environment-friendly cropping management → Regular presentation of innovations and new results that are up to date and on international high level.	In contrast to the field seminar the vocational training is more theoretical, which is less attractive for farmers → Combination of different implementation measures like vocational training for the theoretical background and the field seminar to show the opportunities of technology implementation in practice.
Capacity building → Through better linkage between the actors of different stakeholder groups (see point 1) and by regular teaching/ training and consultation.	
Better knowledge transfer → By presenting practice-oriented project findings, which show the current state of research.	
Improved linkage between different stakeholder groups like specialists, advisers and farmers/ land users → By regular joint vocational workshops and seminars on education, research, consulting, needs of end users with actors of the Agricultural Knowledge and Information System network in the Altai region. For the realization of this purpose the regional "Altai Vocational Training Centre in Barnaul was and can be used as a platform.	
Better consultation of land users and specialists → By presenting practice-oriented project findings, which present the current state of research as well as discussions about the presented issues.	

Contact person(s): Peter Liebelt, Martin-Luther-University Halle-Wittenberg, Germany, peter.liebelt@geo.uni-halle.de

left: PhilRice nursery with flowering plants for ecological engineering. (Photo: Martin Wiemers)
right: Rice field planted with strips of flowering plants along bunds for ecological engineering. (Photo: Leonardo V. Marquez)

Ecological engineering for biological pest control in lowland rice agroecosystems

Philippines

Ecological engineering in lowland rice agroecosystems by planting of flower strips in rice fields as habitats for beneficial arthropods which control pests

To counteract the negative impact of agricultural intensification, in particular the loss of biodiversity and ecosystem services, more sustainable management for crop land and surrounding habitats is required. 'Ecological engineering', in this case meaning the provision of habitats for beneficial arthropods, has recently gained considerable attention as a method of reducing pesticide input, through stimulating biological pest control by natural enemies.

The concept of ecological engineering is aimed primarily at the regulation of pest species, through the provision of habitats for their natural enemies. However, other ecosystem services, such as pollination and cultural services, may simultaneously be enhanced by using the same measures. One such measure, which is popular and effective in temperate countries where agro-environmental schemes are implemented, is the planting of flower strips as habitats.

In intensively managed tropical rice production systems, biological pest control, pollination services and landscape aesthetics could also benefit from the establishment of flower strips on the bunds within irrigated fields. The specific aim of the technology featured here is to increase biodiversity in rice fields and provide habitats for beneficial organisms such as predators of rice pests (e.g. spiders) or parasitoids (e.g. hymenopteran parasites), which in turn will help to minimize the use of pesticides. An additional benefit is landscape beautification.

The process comprises collecting seeds of flowering plants (e.g. flowering annuals such as *Melampodium divaricatum*) and planting them in a nursery. After a month or so they can be transplanted into rice fields on bunds, with a strip size of 0.25 x 5 metres, and a distance between strips of 5 metres (to enable access for farm operations such as fertilizer application). Farmers are requested not to spray insecticides when they test this system. The flowering plants should be pruned during the fallow period in the wet season; and they will require watering during the dry season when rice is cropped. The flower strips will need to be replanted after the rice crop is harvested, if an annual species are chosen.

While this SLM technology is for an irrigated rice ecosystem in the center of the island of Luzon in the Philippines, it has already been applied in other rice producing areas – for example in Vietnam and, with some adaptations, should be applicable to irrigated lowland rice production systems throughout Southeast Asia.

Location: Nueva Ecija
Region: Muñoz
Technology area: < 0.1 km^2 (10 ha)
Conservation measure: vegetative
Stage of intervention: prevention of land degradation
Origin: developed through experiments / research, recent (<10 years ago)
Land use type: cropland: annual cropping
Climate: Humid, tropics
WOCAT database reference: T_PHI065en
Related approach: A_VIE003en (Entertainment- education for ecological engineering)
Compiled by: Leonardo Marquez Philippine Rice Research Institute, lvinasmarquez@yahoo.com.ph
Date: 5th May 2016

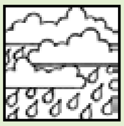
Classification

Land use problems: pest outbreaks; low population of natural enemies; loss of biodiversity and health hazards to farmers. High levels of pesticide use leading to insect resistance. Complete loss of forest leading to degraded watersheds and sedimentation of dams, soil erosion, and temperatures rising as a result of climate change. Intensive agriculture causing degraded soil conditions and compromising the sustainability of productive lands. Intensive agriculture also means increased use of water resources, more chemical inputs and more pest pressure (expert's point of view). Pest problems (land user's point of view).

Land use

annual cropping: full irrigation

Climate

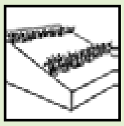


humid

Degradation

biological degradation: increase of pests / diseases, loss of predators

Conservation measure



vegetative: others (annual flower strips)

Stage of intervention

- ■ Prevention
- ▒ Mitigation / Reduction
- □ Rehabilitation

Origin

- □ Land user's initiative:
- ■ Experiments / research: recent (<10 years ago)
- □ Externally introduced

Level of technical knowledge

- ▒ Agricultural advisor
- ▒ Land user

Main causes of land degradation:
Direct causes - Human induced: over-use of pesticides and other agro-chemicals, loss of biodiversity / removal of natural vegetation (incl. forest fires).
Indirect causes: population pressure.

Main technical functions:
- Biological pest control reduces pollution by agro-chemicals
- Promotion of vegetation species and varieties
- Beautification of landscape by flowers

Secondary technical functions:
- Spatial arrangement and diversification of land use

Environment

Natural Environment

Average annual rainfall (mm)

- □ > 4000
- □ 3000-4000
- □ 2000-3000
- ■ 1500-2000
- □ 1000-1500
- □ 750-1000
- □ 500-750
- □ 250-500
- □ < 250

Altitude (m a.s.l.)

- □ > 4000
- □ 3000-4000
- □ 2500-3000
- □ 2000-2500
- □ 1500-2000
- □ 1000-1500
- □ 500-1000
- □ 100-500
- ■ <100

Landform

- ■ plateau / plains
- □ ridges
- □ mountain slopes
- □ hill slopes
- □ footslopes
- □ valley floors

Slope (%)

- ■ flat
- □ gentle
- □ moderate
- □ rolling
- □ hilly
- □ steep
- □ very steep

Soil depth (cm)

- ■ 0-20
- □ 20-50
- □ 50-80
- □ 80-120
- □ >120

Growing season(s): 120 days (January to April), 120 days(June to September)
Soil texture: fine / heavy (clay)
Soil fertility: medium
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: n/a

Soil water storage capacity: n/a
Ground water table: < 5 m
Availability of surface water: good
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic extremes: heavy rainfall events (intensities and amount).
Sensitive to climatic extremes: floods, droughts / dry spells.

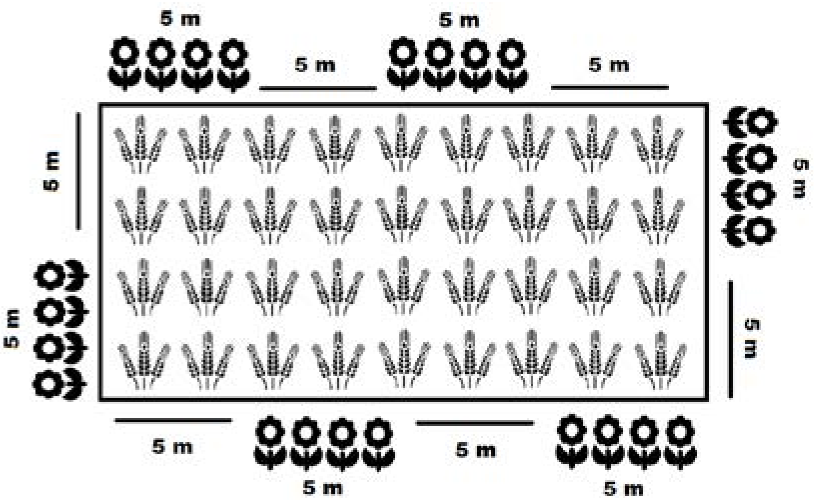
Human Environment

Cropland per household (ha)

- <0.5
- 0.5-1 (selected)
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: groups / community, Small-scale land users, average land users, men and women.
Population density: 200-500 persons/km^2
Annual population growth: 1% - 2%
Land ownership: individual, titled
Land use rights: individual
Water use rights: communal (organised)
Relative level of wealth: average, which represents 70% of the land users; 50% of the total area is owned by average land users.

Importance of off-farm income: > 50% of all Income. < 50% comes from farming
Access to service and infrastructure: low: employment (e.g. off-farm), drinking water and sanitation, financial services; moderate: health, technical assistance, market, energy, roads & transport; high: education.
Market orientation: commercial (rice)
Mechanization: manual labour, mechanised
Livestock grazing on cropland: no



Technical drawing

Flowering plants planted around rice field (e.g. annuals such as *Melampodium divaricatum*) (Martin Wiemers)

Implementation activities, inputs and costs

Establishment activities

1. Flowering plant seed collection
2. Flowering plant nursery establishment
3. Transplanting flowering plants around rice fields /on rice field levees

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	90.00	0%
Agricultural		
– fertilizer	4.00	0%
– compost / manure	30.00	0%
Other		
– plastic bags / pots	19.00	0%
– transportation	41.50	0%
TOTAL	**184.50**	**0%**

Maintenance/recurrent activities

1. Flowering plant maintenance: pruning, removal of volunteer seedlings out of the strips and thinning during cropping season. Watering and replacement in times of prolonged droughts.

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	40.00	0%
TOTAL	**40.00**	**0%**

Remarks: Costs are given for the first year of testing. If flower strips with annual flowering plants will be planted recurrently, then ‘establishment’ costs will be the same each year.

Assessment

Impacts of the Technology

Production and socio-economic benefits	Production and socio-economic disadvantages
+ reduced expenses on agricultural inputs + decreased workload due to less pesticide application activities	− increased labour for establishing and maintenance of flowering plants

Socio-cultural benefits	Socio-cultural disadvantages
+++ improved health + increased recreational opportunities	

Ecological benefits	Ecological disadvantages
+++ increased animal diversity +++ increased plant diversity +++ increased beneficial species +++ increased / maintained habitat diversity ++ increased water quality + increased biomass above ground C	

Off-site benefits	Off-site disadvantages

Contribution to human well-being / livelihoods

++ Farmers in the area were looking for alternatives to pesticides in their rice crop management; they are also aware of the adverse effect of chemicals on their health and to the environment. Farmers need to implement sustainable management strategies for their rice because it is their livelihood: so when they practice ecological engineering for lowland rice and don't use pesticides, they minimized their inputs and protect their health.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	positive	very positive
Maintenance/recurrent	slightly negative	positive

Acceptance/adoption: 90% of land user families (70 families; 90% of area) have implemented the technology with external material support. 10% of land user families (20 families; 10% of area) have implemented the technology voluntarily. There is a moderate trend towards (growing) spontaneous adoption of the technology. The technology has been adapted by farmers connected to PhilRice and technicians from the Department of Agriculture but not yet by all rice farmers

Concluding statements

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
Enhances biodiversity in rice ecosystem → Continue demonstration.	Does not solve all problems with pests, i.e. pest outbreaks are still possible → Develop integrated pest management, e.g. use pesticides only in emergencies, and/or develop an insurance system for farmers.
Farmers save money by reducing pesticide use → Present research results to farmers.	Additional work for farmers→ Incorporate activities in traditional rice growing activities.
Ceasing or reducing pesticide use improves farmers' health → Educate farmers about the harmful effects of pesticide use.	To achieve maximum impact, neighboring farmers and fields should also reduce the use of pesticides and agro-chemicals → A management plan for the whole area needs to be developed

Key reference(s): Westphal, C. et al. (2015) Promoting multiple ecosystem services with flower strips and participatory approaches in rice production landscapes, http://dx.doi.org/doi:10.1016/j.baae.2015.10.004 • http://legato-project.net/

Contact person(s): Josef Settele, Helmholtz Centre for Environmental Research - UFZ, Department of Community Ecology, Theodor-Lieser-Str. 4, 06120 Halle, Germany. josef.settele@ufz.de

left: “Meet the actors” day (Photo: Monina Escalada)
Right: Audience watching a taped TV episode. (Photo: Monina Escalada)

Entertainment-education for ecological engineering

Vietnam - Cong Nghe Xanh

Entertainment-education for ecological engineering involves a series of TV programmes that educate rice farmers about ecosystem services, as well as ecological engineering techniques to conserve biodiversity in rice landscapes.

A multi-stakeholder participatory process was adopted in formative research, then designing and developing a soap-opera series, launching the programme, followed by implementing on-the-ground support, and monitoring of progress. The stakeholders involved were from research, extension, a video production company and local government. To make sure the educational content was accurately and seamlessly woven into drama, the collaborating team was composed of technical experts and scriptwriters, nick-named the ‘‘turtles and peacocks’’. Each 15-minute episode is composed of 3 parts: a short drama by comedians, an explanation by experts, and then a summary of the lesson portrayed in that particular episode.

The LEGATO TV series was produced by Viet Idea, a video company based in Ho Chi Minh City, and was broadcast on Long An TV (LA34) weekly for 20 weeks. The 18 episodes were based on the values grid that LEGATO scientists had developed. They covered a range of topics including organic matter decomposition, organisms and microorganisms, straw burning, rural habitats, the food chain, the architecture of traditional houses, the role of silicon in rice production, honey bees, plant health, ecotourism and eco-engineering.

To popularize and enhance the viewership of the LEGATO Ecological Engineering TV series, a “Meet the Actors Day” was organized in Khanh Hau village, Tan An Town, Long An Province. The organisers comprised “Cong Nghe Xanh”, Long An TV (LA34), Y Tuong Viet (Idea Vietnam), and the Southern Regional Plant Protection Centre. The event was attended by the village People’s Committee Chair, farmers, Long An TV staff and plant protection officers. The “Meet the Actors” day is one of the elements in the entertainment-education approach. To track viewership and audience reactions to the TV series, four focus group discussions (FGDs) were conducted with 41 rice farmers in four villages in Long An province. A post-broadcast survey was carried out in January 2015 among 396 randomly selected rice farmers in Long An and Tien Giang Provinces.

The role of the different stakeholders in the approach was as follows: 1) Farmers provided feedback on the relevance and usefulness of the TV episodes and suggested other topics; 2) Plant protection officers worked with TV episode scriptwriters and served as subject matter specialists to simplify the educational content of each episode; 3) Local plant protection experts provided the scientific explanation behind the topics tackled in the episodes; 4) Local government was represented by Dr Nguyen Van Khang, former Director of Agriculture in Tien Giang province who agreed to allocate a portion of the provincial pesticide budget into ecological engineering demonstrations as he required data to be generated locally. Since then, from 2010 to 2014, more demonstration fields were set up.

Preliminary analyses showed no significant differences in farmers’ insecticide use, but significant differences were found in beliefs and positions about growing flowers, biocontrol, and silicon use. A follow-up farmer survey was conducted to further evaluate the effects of the TV series on rice farmers in Tien Giang and Long An Provinces.

Location: Long An and Tien Giang, Tan An town, Tan Tru, Thu Thua, Ben Luc, Chau Thanh,Tan Phuoc, Cai Lay
Approach area: > 10,000 km^2
Type of approach: recent local initiative / innovative
Focus: on conservation only
WOCAT database reference: A_VIE003en
Related technology: none
Compiled by: Monina Escalada,Visayas State University, Baybay City, 6521 Leyte, Philippines, m.escalada@gmail.com
Date: March 2016

LEGATO
RICE ECOSYSTEM SERVICES

Problem, objectives and constraints

Problems:
Lack of funds to support SLM; Unregulated pesticide marketing continues to negate the gains obtained by SLM.

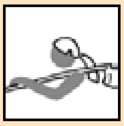
Aims / Objectives:
Improve farmers' pest management, reduce their insecticide use and improve their land use to include conservation of biodiversity.

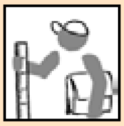
Constraints addressed

	Constraints	Treatments
Technical	Technical information.	Explore research findings for information.
Workload	Lack of work force dedicated to this entertainment-education process.	Encourage provincial government to allocate more staff who can simplify and disseminate scientific information. .
Social / cultural / religious	Educate farmers to appreciate parasitoids that are too tiny to be seen by the naked eye.	As the parasitoids and bees belong to the same insect group, hymenoptera, we associated parasitoids with bees that farmers are familiar with.
Other	Unregulated pesticide sales continue to negate gains from education.	Encourage government to review and reform current pesticide sales regulations.
Institutional	Lack of direct linkage between agricultural and TV broadcasting stations.	Use stakeholder meetings and field activities to establish these new links.
Financial	Funds to support education system.	Encourage local governments to provide support.

Participation and decision making

Stakeholders / target groups


land users, individual


SLM specialists / agricultural advisors


politicians / decision makers

Approach costs met by:	
– government (US$ 30,000)	30%
– international (German Ministry of Education and Research, BMBF; US$ 70,000)	70%
Total	**100%**

Annual budget for SLM component:
US$ 100,000

Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users.
Decisions on method of implementing the Technology: Mainly by SLM specialists with consultation of land users.
Approach designed by: National specialists, land users, international specialists.
Implementing bodies: International (Centre for Agricultural BioSciences International (CABI), Malaysia), international non-government (Visayas State University, Leyte, Philippines), local government (district, county, municipality, village etc) (Local government of Long An Province).

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	Passive	SLM promoters
Planning	Interactive	All stakeholders
Implementation	Self-mobilisation	All stakeholders
Monitoring/evaluation	Self-mobilisation	SLM promoters and local implementers
Research	Interactive	SLM promoters

Differences between participation of men and women: No

Involvement of disadvantaged groups: No

Organogram: Steps in developing and promoting a soap opera (Kong Luen Heong, Monina Escalada)

Technical support

Training / awareness raising: Training provided for land users, field staff/agricultural advisors. Training was on-the-job, demonstration areas, public meetings, communication campaign, site visits / farmer-to-farmer. Training focused on the principles of ecological engineering and pest management.
Advisory service:
Name: Consultation
Research: Yes, little research. Topics covered include ecology. Mostly on-farm research.

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Voluntary
Input:

- Equipment (machinery, tools, etc). Not financed
- Infrastructure (roads, schools, etc). Not financed
- Construction material (stone, wood, etc). Not financed. Transport: transportation of people and materials, partly financed
- Agricultural (seeds, fertilizers, etc): Flower seedlings: partly financed

Credit: Credit was not available
Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
socio-cultural	Regular observations and measurements by land users

Changes as result of monitoring and evaluation: There were no changes in the approach. There were no changes in the technology.

Impacts of the Approach

Improved sustainable land management: Yes, great; Reduction in fertilizer and pesticide use.
Adoption by other land users / projects: Yes, some
Improved livelihoods / human well-being: Yes, great
Improved situation of disadvantaged groups: No
Poverty alleviation: Yes, little
Training, advisory service and research:

- Training effectiveness:
  Agricultural advisor / trainers: good
  SLM specialists: good
  Planners: good
  Land users: excellent
- Advisory service effectiveness
  Politicians / decision-makers: fair
  Technicians / conservation specialists: good
  Land users: excellent
- Research contributing to the approach`s effectiveness:
  Moderately. The research results showed that the ecological engineering practices were beneficial.

Land/water use rights: Low in the implementation of the approach. The approach did not reduce the land/water use rights problem.
Long-term impact of subsidies: Positive long-term impact: None. Negative long-term impact: None

Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production. Increased profitability, improved cost-benefit ratio. Environmental consciousness, morale, health.
Sustainability of activities: It is uncertain whether the land users will be able to sustain the approach activities without support.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
The use of the entertainment-education approach has been found to be highly successful in Vietnam. An post-completion evaluation of a radio drama programme launched in 2004, showed that farmers who had listened to at least two episodes reduced their insecticide spraying by 60%, and their fertilizer and seed rates by 9% and 33% respectively (Heong et al., 2008) → It can be sustained if there is funding to support the activities.	The land users would need to rely on funding to be able to implement this approach, as there are costs attached to producing the TV series.
Our research partners find the use of entertainment-education an easy and rewarding approach to implement as there is often a warm response from the audience, namely farmers, women's groups and local government officials.	An important challenge is the longer-term sustainability of the TV series. The challenge is to mainstream such programmes into the TV station's regular programming. To maintain a long TV series will require funding. A further potential threat to sustain the gains made by the TV series is "advertising piracy" where the TV series is being used to advertise new pesticides.

Key reference(s): Westpal, C. et al. (2015) Promoting multiple ecosystem services with flower strips and participatory approaches in rice production landscapes. Basic and Applied Ecology • Heong, K.L. et al. (2014) Restoration of rice landscape biodiversity by farmers in Vietnam through education and motivation using media. In G. Mainguy (ed) Special issue on large scale restoration of ecosystems. S.A.P.I.E.N.S (online) Vol 7 No. 2. http://sapiens.revues.org/1578. Electronic ISSN 1993-3819 • Heong, K.L. et al. (2008) Entertainment-Education and rice pest management: A radio soap opera in Vietnam. Crop Protection, 27: 1392-1397.
Contact person(s): Josef Settele, Helmholtz-Zentrum für Umweltforschung GmbH - UFZ Theodor-Lieser-Straße 4 Halle, Gemany 06120. Josef.Settele@ufz.de

left: Temporary barrier in drainage canal at Tu Cau irrigation scheme to minimise the water wastage. (Photo: Tran Thi Ha Van)
right: Temporary pump at Sen Pond returning water to prevent drought (Pumping capacity: 15 kW, pumping discharge (Q): 600m3/h) (Photo: Tran Thi Ha Van)

Water saving through reuse of return flow in paddy fields

Vietnam

Return flow from paddy fields is strategically collected before being lost to rivers and is reused as an effective source of agricultural water.

Return flow from paddy fields is defined as applied water that is not lost by evapotranspiration but returns to an aquifer or surface water body (Womach, 2005). The two types of return flow are surface and sub-surface. Surface return flow accounts for the major proportion. If surface return flow is strategically collected before entering rivers, it can be used as an 'extra' effective source of agricultural water supply (Phil King, 2008; Simons et al., 2015). Because paddies effectively purify water by absorbing nitrogen and phosphorus, this produces return flow of an acceptable quality for irrigation purposes. Return flow can be collected by drainage canals and stored in ponds and reservoirs, and then returned to pumps for reapplication. This technology offers one solution towards overcoming a deficit of irrigation water.

The goal of this technology is to store and reuse surface return flow from paddy farms to enhance irrigation efficiency. The purpose of constructing temporary barriers in drainage canals is to minimise water wastage and optimise the possibility of collecting and recycling surface return flow. Return flow from irrigation system is stored in surrounding ponds and reservoirs Return flow can only be used when it is captured in a storage structure or drain which has a hydraulic link to the irrigation source: thus an integrated framework for the reuse system consisting of both hydraulic, and management, links should be established. Within the scope of this study, the Water Management Unit (WMU) is understood as an integrated irrigation and drainage system consisting of four components: (i) the hydrological catchment which covers both non-irrigated and irrigated area; (ii) the source scheme generating return flow; (iii) the reuse scheme that is hydraulically connected with the source scheme; and (iv) a drainage system functioning as a harvesting as well as a supply structure.

Before implementing such a system it is recommended to analyse the correlation between irrigation efficiency and reuse of return flow, as well as developing a framework for managing and recycling return flow. Investigation aims at identifying the potential of return flow for irrigation; determining its quantity and quality; and developing an efficient and sustainable reuse framework. Water balance calculations, field measurements, water quality sampling and interviewing are all used for this purpose.

In the study area, long dry seasons cause severe water shortages and problems with saline intrusion. The study area is mainly covered by paddy, vegetables and other annual crops such as maize, sweet potatoes, peanuts and sugarcane. Paddy rice, which consumes a high proportion of the freshwater, is the dominant crop. Agricultural land in the downstream area is irrigated through gravity or pump irrigation systems. Here results indicate that the irrigation efficiency can be improved significantly: the irrigation efficiency of Tu Cau and Thanh Quyt irrigation schemes is projected to increase respectively by 1.8 and 1.4 times.

Reuse of return flow can be applied in all WMUs where the drainage canals are connected with storage tanks. Scientific and technical support tools are offered by the Vu Gia Thu Bon River Basin Information Centre. The centre was established in Danang providing a comprehensive information service to farmers and other water users – it includes capacity building and consulting services also.

Location: Quang Nam
Region: Dien Ban
Technology area: 0.916 km^2
Conservation measure: structural, management
Stage of intervention: mitigation / reduction of land degradation
Origin: developed through land user`s initiative, recent (<10 years ago); through experiments / research, recent (<10 years ago)
Land use type: cropland: Annual cropping
Climate: subhumid, tropics
WOCAT database reference: T_VIE004en
Related approach: A_VIE002en
(Vu Gia Thu Bon River Basin Information Centre)
Compiled by: Van Tran Thi Ha, Cologne University of Applied Sciences, e-mail: tranhavan@gmail.com
Date: 3rd August 2015, updated June 2016

Classification

Land use problems: The lowland part of Vu Gia Thu Bon is an intensive agricultural area. Rice cultivation, which consumes a high proportion of fresh water, accounts for 70% of total agricultural land (Ribbe et al., 2011). Since 2005, due to the impacts of droughts and saltwater intrusion, water for irrigation during the dry seasons has become an increasing problem in the lowland area of this basin. Simultaneously, the irrigation efficiency of this region is relative low. Various measures are applied to address water scarcity for irrigation. Reusing return flow is regarded as a potentially new measure to reduce the severity of the irrigation deficit in dry periods (expert's point of view). Based on the information provided by the Department of Natural Resources and Environment (DONRE) for Quang Nam Province, this basin now faces the problem of temporarily insufficient irrigation water. This situation is caused by droughts, insufficient reservoir capacity, salinity intrusion and ineffective irrigation management (land user's point of view).

Land use

annual cropping
full irrigation

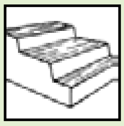
Climate

subhumid

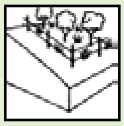
Degradation

water degradation: change in quantity of surface water; decline in surface water quality

Conservation measure



structural: dams / pans: store excessive water: walls / barriers / palisades



waste management: recycling, re-use change of management / intensity level

Stage of intervention

- Prevention
- ■ Mitigation / Reduction
- Rehabilitation

Origin

- ■ Land user's initiative: recent (<10 years ago)
- ■ Experiments / research: recent (<10 years ago)
- Externally introduced: recent (<10 years ago)

Level of technical knowledge

- ■ Agricultural advisor
- Land user

Main causes of land degradation:
Direct causes - Human induced: crop management (annual, perennial, tree/shrub), industrial activities and mining, over abstraction / excessive withdrawal of water (for irrigation, industry, etc.).
Direct causes - Natural: change of seasonal rainfall, droughts.

Main technical functions:
– water harvesting / increase water supply

Secondary technical functions: not applicable

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000
- 3000-4000
- ■ 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- < 250

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- ■ <100

Landform

- ■ plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- ■ flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- ■ 20-50
- 50-80
- 80-120
- >120

Growing season(s): 130 days(20th December to 28th April), 110 days (20 May to 06 September)
Soil texture: medium (loam)
Soil fertility: high
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: < 5 m
Availability of surface water: medium
Water quality: for agricultural use only
Biodiversity: low

Tolerant of climatic gradual change and extremes: seasonal rainfall increase, heavy rainfall events (intensities and amount), droughts / dry spells
Sensitive to climatic gradual change and extremes: temperature increase
If sensitive, what modifications were made / are possible: planting trees and shrubs around the storage reservoirs or using some biological covers such as lily pads and duckweed to reduce evaporation losses.

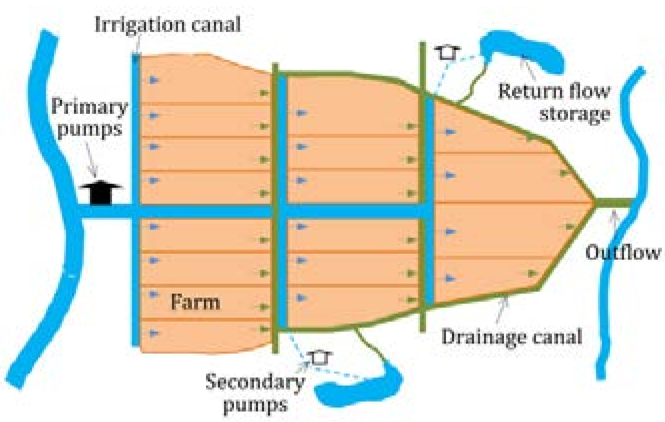
Human Environment

Cropland per household (ha)

■ (black)	<0.5
■ (grey)	0.5-1
	1-2
	2-5
	5-15
	15-50
	50-100
	100-500
	500-1,000
	1,000-10,000
	>10,000

Land user: Individual / household, Small-scale land users, average land users, men and women
Population density: > 500 persons/km^2
Annual population growth: 1% - 2%
Land ownership: state
Land use rights: land user, individual
Water use rights: open access (unorganised)
Relative level of wealth: average, which represents 70% of the land users; 60% of the total area is owned by average land users.

Importance of off-farm income: > 50% of all income: There is a large industrial park located near the study site and a large part of the working population in the region is earning income by working in the factories.
Access to service and infrastructure: moderate: technical assistance, drinking water and sanitation, financial services; high: health, education, employment (e.g. off-farm), market, energy, roads & transport.
Market orientation: mixed (subsistence and commercial)
Mechanization: mechanised
Livestock grazing on cropland: yes little



Technical drawing

Methods of recycling return flow from paddy fields: The surface return flow can be captured by drainage canals and stored in tanks: return water from these reservoirs is pumped back into irrigation canals.
In 2012, the first on-farm irrigation structure was initially implemented in the Tu Cau WMU in order to use return flow for irrigation purposes. The existing Sen Pond was enlarged and a temporary pumping station was installed to pump water into the irrigation canal system.
According to the pumping diary of Tu Cau station (in Winter-Spring crop 2013), there were totally 7 irrigation periods (8-11 days/period). Total input water (including effective rainfall) during the measuring period from 01 March to 10 April was about 28,000 m^3. Meanwhile the total volume of return flow of the Tu Cau site was 16,176 m^3. This amount of return flow has the potential to irrigate the agricultural area for about 16 days, equivalent to one and a half irrigation periods. The overall efficiency of the irrigation system will be significantly improved (Trinh Quoc Viet).

Implementation activities, inputs and costs

Establishment activities

1. Building temporary barrier in drainage canal
2. Dredging and expanding Sen Pond (3 bulldozers, 3 excavators operating in 12 months)
3. Installing and operating the temporary pump at Sen Pond (P is 15KW; Q=520-600m3/h, diesel-run pump: 768.2 US$)

* The total area of Tu Cau and Thanh Quyt irrigation schemes is 5.553 km^2

Establishment inputs and costs per unit*

Inputs	Costs (US$)	% met by land user
Labour	3046.52	0%
Equipment		
– machine use (including pump)	5344.09	0%
– hammer, iron wire	2.40	100%
Construction material		
– stone, sandy bags, bamboo sticks	6.45	100%
– earth, concrete	1335.80	0%
TOTAL	**9735.26**	**0.09%**

Maintenance/recurrent activities

1. Temporary barrier maintenance
2. Temporary pump maintenance

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Labour	24.00	30%
Equipment		
– machine use	38.41	0%
Construction material		
– stone, sandy bags, bamboo sticks	3.22	100%
TOTAL	**65.63**	**15.80%**

Remarks:
Prices of the material and equipment; the approval procedure and disbursement process of the project of “Dredging and expanding Sen Pond”; the compensation cost for the farmers; the cost of operating and maintaining temporary pump; the cost of reinforcing the drainage canals.

Assessment

Impacts of the Technology

Production and socio-economic benefits

+++ increased irrigation water availability quality
+++ reduced demand for irrigation water
+++ Increased irrigation efficiency

Production and socio-economic disadvantages

Socio-cultural benefits

+ improved conservation / erosion knowledge

Socio-cultural disadvantages

Ecological benefits

+++ increased water quantity
++ increased soil moisture
++ recharge of groundwater table / aquifer
++ reduced salinity
+ reduced surface runoff

Ecological disadvantages

− loss of land for enlarging the Send Pond
− contamination of reused water by agro-chemicals

Off-site benefits

Off-site disadvantages

Contribution to human well-being/livelihoods

++ This technology helps to minimise the damage to agricultural production caused by excess salt during the dry periods. It brings the benefits for the farmers by increasing crop yields and thus helps to improve their livelihoods.

Benefits/costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	slightly negative	very positive
Maintenance/recurrent	very positive	very positive

Concluding statements

Strengths and → how to sustain/improve

Using return flow helps to improve irrigation efficiency. The amount of extracted water for irrigation and the cost of operating an irrigation system can be reduced → Reducing evaporation losses from the storage reservoirs.

The measure contributes to mitigating negative impacts of drought and salt intrusion. During the dry season the river water becomes more and more saline due to salt water intrusion. Salinity also builds up from not leaching out salts in the subsoil → Mixing the river water with return flow dilutes the salinity to acceptable levels.

Beneficial/ endangered species might obtain new habitats in the retention area → Extensive land use can help to optimize the habitats for beneficial/ endangered species.

Take advantages of available drainage canals, ponds, reservoirs to reduce the investment costs → Survey available tanks. They can also be defined based on DEM and topographical maps. Reinforce existing the drainage canals.

Acceptable water quality because of the purification function of paddies which removes nutrients from the water → It is necessary to conduct preliminary tests and analyse the quality of return water before recycling for irrigation purposes.

Low costs of conveyance systems because of short distance. More flexibility of allocation because of stable return flow. Less conflict between sectors.

Increases the water depth in paddy fields which helps to improve paddy productivity → Construct temporary barriers in drainage canals for raising the water level in the drainage canals.

Weaknesses and → how to overcome

Temporal and spatial variation causes difficulty in using return flow. The differences in soil type, terrain, storage capacity of the paddy fields and irrigation method (e.g. irrigation techniques, the amount of input water and pumping intervals) are major factors influencing the quantity of return flow → Constructing temporary barriers in the drainage canal helps to minimise the water wastage and optimise the possibility of collecting and recycling surface return flow.

Using return flow might spread diseases, and weed seeds from affected farms to safe farms → Encourage farmers to comply with the principles of prevention and control diseases in agricultural production. It is necessary to implement preliminary tests and analyses the quality of return water before recycling for irrigation purposes.

Key reference(s): Kim, H. K. et al. (2009) Estimation of irrigation return flow from paddy fields considering the soil moisture. Agricultural Water Management, 96(5), 875–882. • Phil King (2008) Return Flow Efficiency. New Mexico Water Resources Research Institute. • Simons, G.W.H. et al. (2015) Water reuse in river basins with multiple users: A literature review. Journal of Hydrology. 558–571. • Ribbe et al. (2011) Annex 2 to Milestone Report 2011 - Description of the Study Region including an updated stakeholder analysis, LUCCi project. ITT, Cologne University of Applied Sciences.
Contact person(s): Van Tran Thi Ha, Institute for Technology and Resources Management in the Tropics and Subtropics (ITT), TH Köln, Germany. tranhavan@gmail.com • Viet Trinh Quoc, ITT, TH Köln, Germany. trinhquocviet1981@gmail.com • Hai Nguyen Dinh, Irrigation Management Company Quang Nam, Tam Ky city, Quang Nam province, imcquangnam@gmail.com

left: Stakeholder meeting organized by River Basin Information Centre, RBIC (photo: ITT, LUCCi project)
right: Training course on "Tools for River Basin Management" offered to the stakeholders in Da Nang (photo: ITT, OticProduction)

Vu Gia Thu Bon River Basin Information Centre

Vietnam- *Trung tâm thông tin lưu vực sông VGTB (Vietnamese)*

The VGTB River Basin Information Centre (VGTB-RBIC) offers decision-support tools for stakeholders, and aims at providing comprehensive information and consulting services to water and land users, according to their demands.

Sufficient and sustainable water resource management at river basin scale can only be achieved if it is based on dialogue between all relevant stakeholders, and supported by adequate data. It follows then, that a robust system of monitoring, evaluation, reporting and communication is needed. The lack of appropriate management strategies which would bring these tools together has been underlined by stakeholders, and observed by researchers, involved in the research project LUCCi - Land Use and Climate Change Interactions in the VGTB River Basin. In order to offer a comprehensive decision-making support system, based on scientific knowledge and research results, the Institute for Technology and Resources Management (ITT, TH Köln, Germany) in cooperation with the Vietnam Academy for Water Resources (VAWR, Hanoi, Vietnam) established the VGTB River Basin Information Centre in Da Nang. The overall objective of RBIC is to support efficient and sustainable water and land use. The support provided for the implementation of the water saving technology for paddy systems is one of the services offered by the centre.

The VGTB RBIC is an independent, local institution administrated by the German and Vietnamese coordinators of LUCCi, financed by project sources and located at the Central Department of the Vietnam Academy of Water Resources in Da Nang. As a scientific organization, the VGTB RBIC provides the advantages of impartiality, a detailed knowledge base and a broad interdisciplinary perspective. Through different dissemination activities, such as visits to relevant institutions, information material (brochures, flyers in Vietnamese) as well as training courses and capacity building measures, the relevant stakeholders are well-informed about the activities of the Information Centre. On demand, the following products and services are provided in the VGTB-RBIC: (a) Thematic maps on land use, hydrology and river basin development; (b) A comprehensive database of the VGTB river basin (VGTB RBIS - River Basin Information System, open source) (c) VGTB State of the Basin Report as a decision-support instrument: the report was prepared by the LUCCi research team and provides relevant information on climatic, environmental and socioeconomic data and trends; (d) Hydro-meteorological, hydrograph and salinity data; (e) Flood and drought risk assessment; (f) Scenarios and modelling (reservoir operation, salinity intrusion, irrigation management scenarios); (g) Organization of meetings and discussions on key issues of the development of the VGTB; (f) Training and capacity building services related to the demands of stakeholders.

Thus a heterogeneous stakeholder platform has been established in the case study region that includes scientific institutions, policy makers, public administration representatives as well as private sector companies. It is clear that the major problems of the VGTB River Basin can be only addressed, and adequate solutions identified, if based on active cross-sectoral stakeholder participation. Therefore, the interaction among stakeholders and RBIC plays a key role: the services are offered for the stakeholders, and stakeholder feedback is the basis for providing adequate information services and conducting applied based research.

Location: Da Nang, Central Vietnam
Approach area: 12.38 km^2
Type of approach: Project / programme based
Focus: Mainly on other activities
WOCAT database reference: A_VIE002en
Related technology: T_VIE004en (Water saving through reuse of return flow in paddy fields)
Compiled by: Justyna Sycz, University of Applied Sciences, Cologne, Germany
justyna.sycz@fh-koeln.de
Date: 27th July 2015, updated June 2016

LUCCi

Problem, objectives and constraints

Problems:

The lack of communication between the relevant institutions and water users, the demand for comprehensive decision-support instruments, difficulties with data availability - typically distributed and available at different institutions, as well as conflicts over resource use, were the main problems addressed by the approach. The conflicts caused by the rapid expansion of hydropower since 2008 in the VGTB river basin have especially demonstrated the inadequate participation of local stakeholders in planning processes. Hydropower development has adverse effects on downstream water availability, especially during the dry season, affecting drinking water supply and irrigation.

Aims / Objectives:

1. Establish a communication platform to discuss water and land use related problems, and create transparency among water users.
2. Support and foster the science-policy-society dialogue offering a cross-sectoral neutral space for discussion, consulting and capacity building for all stakeholders and water users (farmers, decision-makers, public institutions, private sector companies).
3. Provide a comprehensive information service and decision support system to stakeholders according to their demands. The following specific products and services are provided by the VGTB-RBIC: Thematic maps on land uses, hydrology and river basin development • Comprehensive database of the VGTB river basin (VGTB RBIS - River Basin Information System, open source) • VGTB State of the Basin Report as a decision support instrument: the report was prepared by the LUCCi research team and provides relevant information on climatic, environmental and socioeconomic data and trends • Hydro-meteorological, hydrograph and salinity data • Flood and drought risk assessment • Scenarios and modelling (reservoir operation, salinity intrusion, irrigation management scenarios) • Organization of meetings and discussions on key issues of the development of the VGTB • Training and capacity building services related to the demands of stakeholders.

Constraints addressed

	Constraints	Treatments
Technical	A robust system of monitoring system was missing in the region: hydro-meteorological data, monitoring of water quantity.	A monitoring network has been established as part of the LUCCi project.
Other	Lack of information about the river basin in order to underpin decision-making.	A “State of the Basin Report” including all available data and information about the river basin has been prepared (climatic, environmental, hydrological, land use and socioeconomic data and trends); River Basin Information System: Comprehensive database of the VGTB river basin through the open source VGTB River Basin Information System.
Institutional	Lack of communication between the institutions and inadequate stakeholder involvement in the decision-making process.	VGTB RBIC offers a cross sectoral communication platform and bring together all relevant stakeholders: organization of workshops and meetings as well as visits to the relevant institutions.

Participation and decision making

Stakeholders / target groups

politicians / decision makers

Approach costs met by:

– International (German Federal Ministry of Education and Research, BMBF)	70%
– National (Vietnam Academy for Water Resources, VAWR)	30%
Total	**100%**

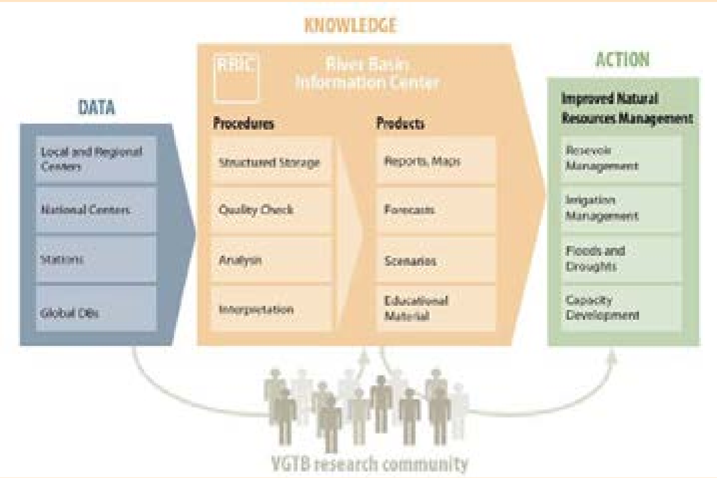
Annual budget for SLM component: US$ 2,000 per year for SLM component

Decisions on choice of the Technology: Mainly by SLM specialists with consultation of land users.
Decisions on method of implementing the Technology: Mainly by SLM specialists with consultation of land users.
Approach designed by: National specialists, international specialists.
Implementing bodies: National and international researchers involved in the LUCCi project, national non-governmental agencies; authorities of a Water Management Unit (WMU).

Land user involvement		
Phase	**Involvement**	**Activities**
Initiation/motivation	Passive	Stakeholder analysis (including all interested groups)
Planning	Passive	Local and regional decision-makers are involved: workshops, discussions and surveys in order to collect relevant socio-economic and land use data, identify research demand and challenges
Implementation	Interactive	Land user decide on whether and which technologies they want to implement
Monitoring/evaluation	None	
Research	Interactive	Land users provide relevant information and data on their farms (size, yields) for research purposes. "Aims/Objectives" elaborated and prepared for the stakeholders by Vietnamese and international researchers based on scientific results and data from land users.

Differences between participation of men and women: No

Involvement of disadvantaged groups: No



Organigram:
Supporting the process from knowledge to possible action: from data and information collection, data quality check and analysis to providing information to users and decision makers (LUCCi project).

Technical support

Training / awareness raising: Training provided for decision-makers/ experts/ local scientists. Training was through demonstration areas. Training focused on key aspects of an integrated river basin management (monitoring, data management and hydrological modelling); current situation, development and challenges in the VGTB river basin; training in the use of appropriate tools and technologies (alternative irrigation strategies for paddy fields: reuse of return flow etc).
Advisory service:
Name: River Basin Information Centre - RBIC
Key elements:
1. Stakeholder Workshops
2. Training on alternative irrigation strategies for paddy fields: reuse of return flow
The extension system is fully adequate to ensure continuation of activities. Researchers (VAWR): can offer training and conduct dissemination activities; Local institutions (e.g. People's Committee of Quang Nam Province): training, dissemination activities, financial support.
Research: Yes, great research. Topics covered include sociology, technology, hydrological modelling. Mostly on-station research. The implementation of return flow from paddy fields as an alternative irrigation technology under local conditions was performed under the framework of LUCCi project (ITT).

External material support / subsidies

Contribution per area (state/private sector): No
Labour: Not financed
Input: Not financed.
Credit: Credit was not available
Support to local institutions: Yes, great support with research, training. Training for decision-makers and professionals; Research: hydrological modelling.

Monitoring and evaluation

Monitored aspects	Methods and indicators
management of Approach	Ad hoc observations and measurements by project staff

Changes as result of monitoring and evaluation: There were several changes in the approach. The approach was based on stakeholder-research interactions. The approach's objective and methodology was adapted to the local conditions and challenges.
The structural concept of the River Basin Information Centre (RBIC) was designed by being based on information demand surveys conducted with representatives of key institutions in water management sector in the provinces of Quang Nam and Da Nang (Master Thesis, Martina Pietrzyk, 2014). Environmental monitoring gaps, information needs and demands for professional training activities and capacity development have been identified and are used as methodological guideline for services and information products offered by RBIC.

Impacts of the Approach

Improved sustainable land management: Yes. Decreased water use; efficient resource management
Adoption by other land users / projects: No
Improved livelihoods / human well-being: Yes, little
Improved situation of disadvantaged groups: Yes, little
Training, advisory service and research:

- Training effectiveness:
  Agricultural advisor / trainers: good
  Politicians / decision makers: good
  SLM specialists: good
  Planners: good
- Advisory services effectiveness
  Politicians / decision-makers: fair
  Planners: fair
- Research contributing to the approach's effectiveness:
  Greatly. research is not finished yet

Long-term impact of subsidies: Positive long-term impact: None
Negative long-term impact: None
Subsidies weren´t available for the implementation of the technology

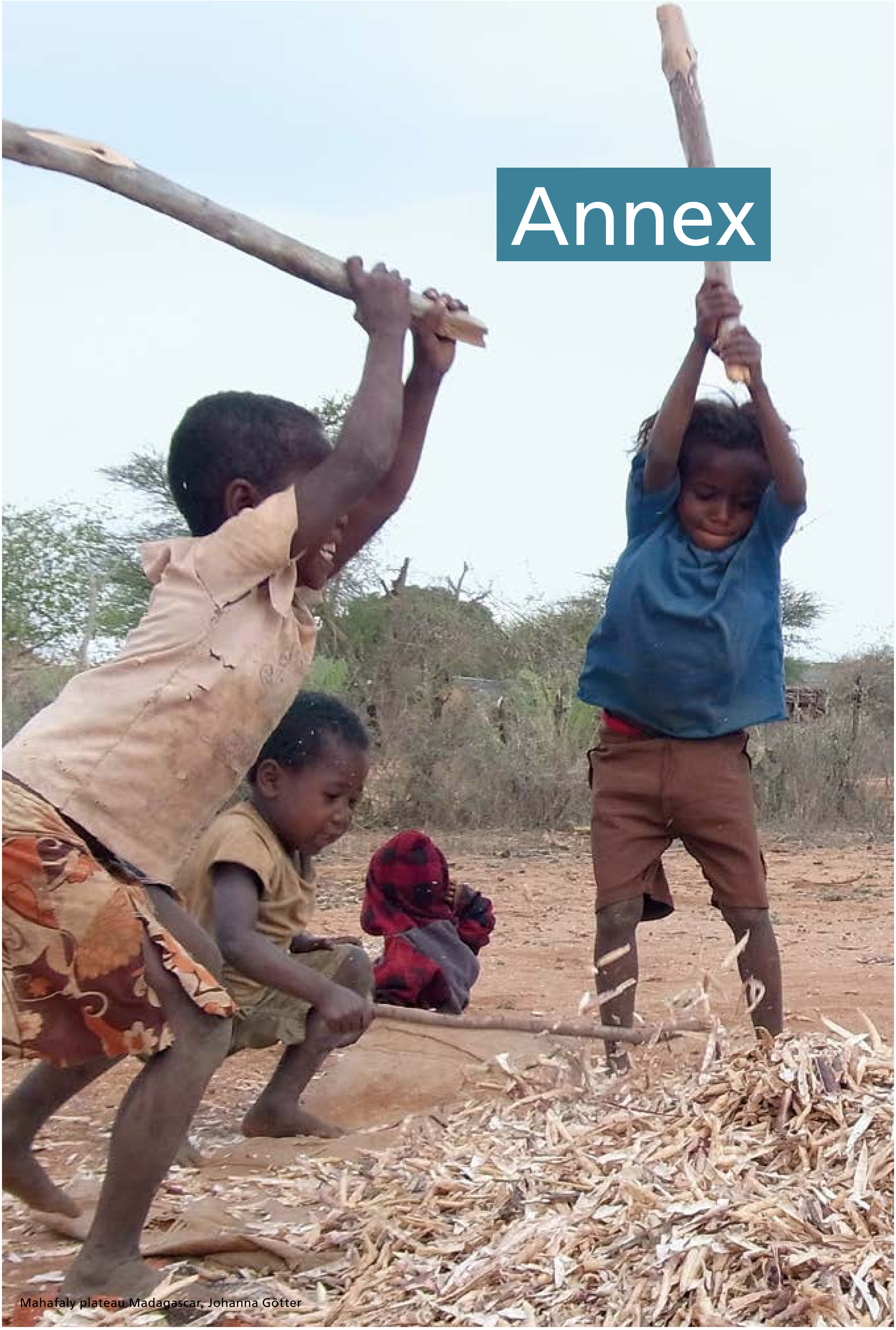
Conclusions and lessons learnt

Main motivation of land users to implement SLM: Production; well-being and livelihoods improvement: Increase water use efficiency.
Sustainability of activities: The land users can sustain the approach activities if financial resources can be mobilized.

Strengths and → how to sustain/improve	Weaknesses and → how to overcome
The approach is managed by researchers. This has the advantages of impartiality, a detailed knowledge base and a broad interdisciplinary perspective.	The VGTB RBIC is a new institution, unknown to the local stakeholders → Provide dissemination activities and training in order to explain the decision making process and the role of the VGTB RBIC as a support instrument.
Adaptability to stakeholders' needs → Strong interaction between the management of the VGTB RBIC and regional stakeholders is necessary: organize regular meetings and workshops; Stakeholders regularly inform the centre about their information requirements.	The approach was developed as part of a research project. There is the risk that the scale of activities and services will be reduced after the end of the project duration → Try to obtain financial resources by the local and public institutions in order to develop and manage the centre after the end of the project.
Monitoring, evaluation, reporting and communication are integrated, summarized and carried out by one institution.	It needs long-term commitment from research, from extension, and from the government to support such a service for the benefit of all people and the environment.

Key reference(s): Ribbe, L. et al.(2016) Integrated River Basin Management in the Vu Gia Thu Bon Basin, in: Nauditt, Ribbe (editors) Land Use and Climate Change Interaction in Central Vietnam, Springer Book Series Water Resources Management and Development
Contact person(s): Alexandra Nauditt, University of Applied Science, TH Köln, Germany: alexandra.nauditt@th-koeln.de • Lars Ribbe, University of Applied Science, TH Köln, lars.ribbe@th-koeln.de • Phong Nguyen, Vietnam Academy for Water Resources, Hanoi, Vietnam, phongicd@gmail.com

Annex



Mahafaly plateau Madagascar, Johanna Götter

Figure 2: Participants of the kick-off and 1st synthesis workshop, January 2015. (Andreas Werntze)

Figure 3: Participants of the kick-off and 1st synthesis workshop, January 2015. (Andreas Werntze)

BMBF-SLM Programme and the regional research projects

Background/ objective

The overall aim of the 'Bundesministerium für Bildung und Forschung – Sustainable Land Management Programme' (BMBF-SLM) funding mechanism was to contribute to the development and implementation of practical solutions to global and regional challenges of land management. The aim was to develop new perspectives for the responsible use of scarce land resources.

Module A of the programme, in which the research and production of this book were conducted, focussed especially on the interactions between land management, climate change and ecosystem services. In the call for the programme the BMBF wrote that, in particular, the interactions between land, climate change, and ecosystem services are multi-dimensional, complex and not yet fully understood (see http://nachhaltiges-landmanagement.de/en/module-a/overview/).

The topic of sustainable land management was deliberately selected as it brought together the formerly separated research topics of climate change mitigation, biodiversity, ecosystem function and services, and global water cycles. These topics have been strong and repeatedly addressed by BMBF calls in the past 15 years. Sustainable land management was seen as an opportunity to collate results from these earlier research programmes. High expectations were expressed about the inter- and transdisciplinary, that is stakeholder-integrated, nature of research. The ultimate goal was to provide people in the study regions with ideas and scientific knowledge for implementation of more sustainable land management. The research institutes that participated were asked to indicate in their research proposals – right from the beginning – a major research period and respective tasks, as well as to specify an 'implementation phase' in which practice-oriented results would be communicated and further elaborated in cooperation with local practitioners.

For these ambitious tasks the BMBF acknowledged that 'a new kind of research' would be needed; that is integrated and integrative, transdisciplinary, implementation-oriented research (IOR). To be able to fulfil such requirements the constituent projects were decided to be relatively large with a multitude of disciplines participating in each case. The overall funding measure was substantial: altogether some 115 million Euros. And it had a relatively long funding period of altogether seven years (five years for individual regional projects): 2010 – 2016/17.

Scientific coordination and stakeholder work - GLUES

To support integration of overall results, the programme was set up with a 13th project that fulfilled the role of scientific and practice / stakeholder coordination and integration. This project named GLUES (Global Assessment of Land Use Dynamics, Greenhouse Gas Emissions and Ecosystem Services) supported, right from the very beginning, outreach work for the overall programme. It facilitated meetings among the regional projects (RPs), and conducted global scenario development and modelling that helped to give another perspective to some of the results of regional modelling efforts conducted in the RPs. GLUES also developed a geodata infrastructure and invited all RPs to make use of it, so that data would be more accessible to the partners within the programme and beyond (see Figure 1 for an overview of GLUES activities).

Figure 1: Overview of GLUES activities (http://modul-a.nachhaltiges-landmanagement.de/en/scientific-coordination-glues/ accessed 30.9.2016).

Figure 4: Presentation of an early draft of Chapter 6. (Hanspeter Liniger)

Figure 5: Impression from one of the writing sessions. (Hanspeter Liniger)

With respect to the tasks of integrating stakeholders from land management practice, GLUES conducted a stakeholder analysis of worldwide active institutions and organisations in sustainable land management. With regular meetings among the RPs, GLUES offered space and time for facilitated learning from each other concerning the challenges involved with implementation-oriented research, stakeholder analysis and communication, preparation and conduct of the implementation phase etc.

A special challenge was documentation and evaluation of learning ('lessons learned') from the activities that the RPs conducted concerning practice results. It was in the context of this work that the idea was born to make use of the WOCAT method. WOCAT (the World Overview of Technologies and Approaches) itself seemed an ideal partner to support the specific challenges involved.

Peter Moll and Ute Zander, as the partners within GLUES responsible for science – practice work, therefore made contact with Hanspeter Liniger and Rima Mekdaschi Studer of WOCAT in 2012. It took then nearly three more years before the work finally started. Placed at the very end of the BMBF-SLM programme, what was initially termed the 'GLUES-WOCAT book', became an important overall outcome of the whole programme.

Bringing it all together

The content of this book has been assimilated together in close cooperation with the 12 regional projects. In particular, the coordinators of the RPs contributed through 'synthesis workshops' (Berlin - Jan 2015, Nov 2015, May 2016) with inputs in writing, open discussion of results, and material such as graphic illustration and photos. In particular their openness to share results of work in progress, unpublished material, and last not least personal experiences in the countries where the research and practice work took place, made this book possible.

Figures 2-5 give an impression of the work behind this book.

In the following the 12 research projects are briefly introduced. The regional context of the specific project, its major results, and key messages are described and a contact address and weblink for further information given.

View on the Agricultural Pioneer Front along the Highway BR-163 in southern Amazonia, Pará, Brazil. (Photo: Gerold, Novo Progresso, October 2013)

Carbocial – Carbon-optimized land management strategies for southern Amazonia

Background / regional context

The German-Brazilian Carbiocial-Carbioma project jointly investigated viable carbon-optimized land management strategies in southern Amazonia. The project tried to understand main parameters towards maintaining carbon stocks and reducing greenhouse emissions in the cerrado and rainforests of northern Mato Grosso and southern Pará in Brazil. Involved subprojects worked on soil, water, climate, agro-economics, land use modelling as well as on socio-economic and political conflicts in the region. Carbiocial identified possible entry-points for advisable change in local and regional production patterns while considering local livelihoods, as well as national and global economic and political aspects.

The project

Main study regions were next to the cities of Novo Progresso (Pará), Sinop (northern Mato Grosso) and Campo Verde (central Mato Grosso). They composed a climatological as well as land use gradient along the recently built highway Cuiabá-Santarém BR-163. The project delivered decision tools based on regional data and modelling of future land use scenarios with the intention to integrate improved carbon storage, social wellbeing and ecosystem services into more sustainable management of the agro-landscapes in the southern Amazon. Physical, geographical and social sciences were used to investigate improvements for the future of the Amazon. They all contributed to evaluations of seasonal changes of water balance components for land use change and climate change scenarios for macro-catchments in the Cerrados (savannas of Central Brazil) and rainforest regions. SWAT simulation analyses concerned forest conversion and conservation on water balance components with regards to land use types. Based on GHG-emission measurements for the main land use types, GHG-models were used to estimate regional GHG-emissions under different land use scenarios. Meso-scaled status quo and scenario erosion simulations (EROSION-3D) allowed predictions of endangered erosional sites. With identification of 'sediment pass over points' carbon content in eroded soil particles was analysed that allowed predictions of lateral carbon fluxes. Discharge and erosion modeling in the studied catchments showed the importance of native gallery forests and modern agro-technical land management (e.g. no-tillage systems, contour earth bunds) to minimize sediment delivery and carbon loss to the rivers.

Major results

The modeling of soil organic carbon processes allowed to calculate turnover times and showed SOC-stock changes for Ferralsols and Acrisols, regarding different land-use scenarios in Mato Grosso and Pará. Soil type differentiation has greater importance than land use type to explain carbon stock differences. Also long-term positive effects on carbon storage capacities of no-tillage systems and pasture, as part of integrated land use systems was proofed. Differences in litter decay rates among land use systems were based on the different litter qualities: soil meso-fauna and macro-fauna accelerated litter decay regardless of litter type, land use, season or studied region. The addition of organic matter waste from industry (e.g. filter cake sugarcane) every two years can increase significantly SOC in Red Latosol from the cerrado, regardless the tested organic matter type. The on-farm study tried to demonstrate that SOC in tropical farmland can be enhanced by applying local available organic matter.

Key messages

On a local scale, socio-ecological conflicts were strongly influenced by discourses on global agro-economic development and nature regulations. Satellite image based time series on long-term deforestation dynamics along the BR-163 highway showed the extents of regrowth, duration, lag time between deforestation and regrowth, and frequency of regrowth cycles. Results show that the Brazilian ABC-program (the Brazilian 'Low Carbon Agriculture Program' aiming to reduce deforestation by 2020 in the Amazon by 80% and in the Cerrado by 40%) has a significant impact on land use and a positive influence on adoption if fully integrated into agro-silvo-pastoral systems. For the first time, MONICA-simulations (simulation model for nitrogen and carbon dynamics in agro-ecosystems) of yields and yield gaps under "climate change" and technological improvement were done for Mato Grosso and Pará. Response on extreme weather events in spatial and temporal discretization could be simulated, so that first yield maps (corn-soybean rotation, cotton) with nitrogen and water constraints were developed (time frame: 2001-2030). While trying to support lasting effects in the region, Carbiocial spread applicable decision support tools and short policy briefs to relevant agricultural institutions, local people and other stakeholders to support mid- and long-term planning along the BR-163. With publishing and distributing the book "Sempre pra Frente" the project gave back results and lessons learned to the local people who could profit most from its results and possibly enjoy a better future in the Amazon.

Contact / more information

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www.carbiocial.de/project/

CC-LandStraD
Climate Change — Land Use Strategies

Diverse land use in Germany: agriculture, forestry, settlement and transportation. (Photo: aid infodienst, Bonn)

CC-LandStraD – Interdependencies between land use and climate change – Strategies for a sustainable land management in Germany

Background / regional context

The question of how to use land in Germany - in the context of climate change - often triggers conflicts because of differing social demands. Opinions vary on how much land should be used for the production of food, energy and wood, or for human settlement and transport. Additionally, the type and intensity of land use significantly affects the environment and the landscape, and thus the recreational value of particular regions. Currently, about half of the land in Germany is used for agriculture, one third for forestry and about 14% for human settlement and transportation. The potential of land management to contribute to climate mitigation depends on complex interactions between land use changes and the bio-geosphere.

The project

The project analysed interactions between different forms of land use and climate change, and assessed the possible contribution of land use strategies to climate change mitigation in Germany. The particular goals were to:

- develop cross-sectoral land use scenarios for agriculture, forestry, human settlement and transportation based on a dialogue with stakeholders,
- analyse conflicts between land use strategies and other social demands and feedback from global markets, and
- derive sustainable land use strategies for the study regions, which would help to achieve the national climate change (CC-) mitigation goals and could be legally implemented in practice.

CC-LandStraD applied inter- and transdisciplinary research methods and approaches. Based on existing global climate scenarios and forecasts of long-term economic development, land use scenarios were developed and modelled spatially differentiated for Germany. Interdisciplinary models helped researchers to analyse interactions between land use and climate change, and to provide scientific knowledge for stakeholders and decision-makers. Biophysical and socio-economic models have been applied to demonstrate the outcomes of land use change. In addition to social requirements legal frameworks were also considered.

CC-LandStraD conducted participatory and transdisciplinary multistakeholder dialogues that included sectoral and cross-sectoral meetings and workshops over the project period of five years. To determine the most relevant individual measures which could contribute to reducing GHG emissions, knowledge from stakeholders and researchers was brought together by establishing an open dialogue platform.

Major Results

The scenarios and models showed that most potential for more sustainable land management in Germany are with;

- High-quality inner urban development
- Adapted management of organic soils: re-wetting, extensive grassland cultivation, paludiculture
- Grassland preservation

Land use is not only the sum of a high number of individual and conflicting decisions on the ground but is strongly influenced and rapidly changed by regional, national and international framework conditions. Land use governance, therefore, has to address all these different and interacting levels of decision-making.

Key messages

Settlement and transportation:

- The "30 hectare aim" of the German government projecting a reduction of daily land consumption to (only) 30 hectares by 2020, cannot even be reached by 2030 with business-as-usual. Further initiatives focusing especially on inner urban development are needed.

Agriculture and forestry:

- When following a 'business-as-usual' pathway, only a narrow decline in GHG emissions can be achieved.
- The reduction potential of all analyzed scenarios compared to the business-as-usual scenario sums up to 10-20%.
- There is a wide cost range for GHG reduction, for example when implementing rewetting measures of organic soil ≤100 Euro/t CO_2 equivalents.
- The bioenergy lines analyzed (e.g. for biogas) are more expensive with >200 Euro/t CO_2 equivalents, largely showing a negative impact on the environment with, in the long run, higher avoidance costs.
- Overall costs for CC-mitigation in agriculture and forestry are particularly high.

Contact / more information

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"We have to adapt to climate change. The drainage system is not capable of dealing with future structural changes."

Typical coastline of the North Sea. (Photo: M. Kleyer)

COMTESS – Sustainable coastal land management: Trade-offs in ecosystem services

Background / regional context

Sea level rise, stronger storm surges and heavier rainfall in winter are the potential consequences of climate change that could threaten coastal regions of the North and Baltic Seas. The collaborative project COMTESS (Sustainable COastal Land Management: Trade-offs in EcoSystem Services) investigated impacts of existing and new land use strategies in the coastal areas on ecosystem functions and services under the influence of climate change. The researchers analysed environmental, economic and social conditions and assessed different land management options from socio-ecological and economic angles.

The current coastal zone management is mainly based on the construction of sea walls and a dense drainage network. The coastal areas below see level would be flooded - from sea and freshwater discharge - and land use would not be possible without the protection by sea walls and the freshwater regulation system. However, sea level rise and extreme weather events will reduce the effectiveness of these measures and will be a great challenge for future land management.

While considering different land management options, as well as local ecological and socio-economic conditions, COMTESS has provided new land use strategies, assessed and quantified ecosystem functions and services, and extrapolated results to the landscape level by statistical and process-based models. Together with SLM-practitioners, decision-oriented recommendations for promoting the sustainable use of vulnerable coastal areas have been developed. Based on these findings, COMTESS has contributed scientific and action-oriented knowledge to the design of multifunctional coastal zone management.

The project

The inter- and transdisciplinary studies investigated possible adaptive land management options. In the "trend" land management option, a continuation of the current land management is expected. This form of management, however, may be seriously affected by flooding and associated costs for drainage, which reduce its ecological and economic viability.

The option "water management / multiple land use" (for the North Sea and Baltic Sea), is for investigating the influence of water retention areas (at the North Sea) and managed realignment (at the Baltic Sea) on the drainage capabilities and on salinization. The primary goal was to strengthen the resilience of the coastal zones against sea level rise and increased winter precipitation. The "carbon sequestration" option would lead to areas dominated by unused reed beds that contribute to active peat accumulation. This land management option is also an example of how natural vegetation can be restored if agricultural land use is abandoned. These three land management options serve as basis for the "actor-based" land management option, developed by local and regional stakeholders. Interviews and other qualitative and quantitative research methods have been used to develop a future land management plan according to the desires, expectations and interests of the participating public and decision-makers.

For each of the four land management options ecosystem functions and services have been quantified until 2100. The evaluation of the land management options will be based on the ecosystem services.

Major results

The core recommendations are regionally adapted lay-outs of land uses as documented by the COMTESS land management options, which include large water retention areas ('polders') for the North Sea region. Floods can be restricted to the polders when the drainage network is no longer capable of discharging excess freshwater resulting from increasing precipitation and sea water levels. The retained freshwater in these water retention areas may be used during dry periods for irrigation. Additionally, subsurface saltwater intrusion in the area could be prevented by polders filled with freshwater.

At the Baltic Sea coast, managed realignments can improve the resilience of the coastal region against sea level rise and increase in winter rainfall. Natural drainage is enabled in the de-embanked areas. Due to more natural hydrological conditions, intensive agricultural land use is not possible any longer but a development towards more natural plant and animal communities can take place with increasing biodiversity.

The interaction of scientists and stakeholders has demonstrated that participatory planning required time to achieve sustainable land use management and to take into account the different goals and needs of the various societal sectors. A coastal adaption strategy that is accepted and supported by all stakeholders is a critical issue for the long-term success of sustainable coastal land management. At the North Sea region, the main results of the actor-based scenario have been implemented in the formal regional planning plan.

Key messages

- Multifunctional landscapes contribute to a climate-proof land use: a change to multifunctional land use can help to avoid expensive investments in climate adaptation.
- Effective water management is only possible with adapted land use in some parts of the landscape; in the case of COMTESS within the water retention areas / managed realignment.
- Raise stakeholders' awareness of possible impacts of climate and find sound solutions together with stakeholders to deal with impacts for successful implementation.

Contact / more information

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Environmental and societal impacts of large hydropower dams – sustainable land and water management in semiarid regions under climate change. (Photos: INNOVATE)

INNOVATE – Interplay among the multiple uses of water reservoirs via innovative coupling of substance cycles in aquatic and terrestrial ecosystems

Background / regional context

Since the 1980s, reservoirs and hydropower facilities within the large São Francisco river basin in the semi-arid Northeast of Brazil have been a key part of the development strategy. Besides providing electricity, rural economic development has been the major focus. However, development of hydropower has not been easy for people living in the river basin, nor for adjustments of the ecosystem or rural agriculture. In the case of the Itaparica reservoir, for example, about 40,000 residents have been resettled. Whereas municipal and agricultural land management schemes primarily targeted irrigation, in reality land use options increasingly suffer from poor soils with low organic matter content. Water quality continues to be reduced by lack of adequate agricultural and aquaculture practices; especially in the large water reservoirs. Insufficient water management strategies and a disregard of smallholders grazing needs and perspectives outside the usual irrigation schemes are strongly contributing to degradation and loss of water. Until today keen competition over water quantities and usage persists.

The project

INNOVATE is a consortium of about 100 scientists from Brazil and Germany. The collaborative project studied the aquatic and terrestrial land management systems, with their underlying ecosystem functions and services. Alternatives such as modified fishery systems, biochar for soil structure improvement, and systems for smallholder cattle farming have been studied, all aiming at improved practices and better socio-economic perspectives. Biodiversity functions and patterns of the predominant caatinga ecosystem were assessed, global climate scenarios down-scaled, the water basins multi-level governance system analysed, and water quality impact by land use estimated. The practitioners addressed involved federal and state agencies, local land-users, civil society actors, and institutions such as the water basin committee with its task of developing a new 10-year development plan.

Sampling, monitoring, surveying and experimental designs have been applied in local studies while large-scale studies primarily modelled potential future impacts of resource use. Stakeholder analyses identified major players, research partners, institutions and actors suitable for implementing results. The current formulation of a new 10-year river-basin management plan served as a focal point. In this context a continuous communication process has been set up between INNOVATE and responsible actors, including the river basin committee. Stakeholder workshops, environmental education campaigns and methodological courses complemented the inter- and transdisciplinary as well as implementation-oriented approach.

Major Results

Management decisions on the allocation of scarce water resources proved the major driver of land use discourses and practices. A major challenge concerns better interaction of more recent and regional (river basin committee) and established bodies (often federal agencies). The present, primarily hydroelectricity-focused water and energy management is likely not to be maintained at the same size or in the long run. Complementary electricity generation offers more integrative pathways for competing water usages.

However, initial concerns regarding the river and reservoir water quality and possible greenhouse gas emissions have not been confirmed. The land-water nexus has further been addressed with the 'green-liver' approach, aiming at purification of effluents from land-based fish production.

For the non-irrigated caatinga ecosystem INNOVATE researchers recommended limited stocking rates, and preserving natural habitats along existing and new irrigation schemes. Restoration measures for endemic trees have been demonstrated. Implementation largely depends on future support, for example from the Brazilian rural development agency. To improve the productivity of the agro-ecosystems, locally available and economically feasible substrates for soil amelioration have been identified and tested. Such practices require further guidance from the Brazilian agricultural research agency. The persistent drought crisis acts as a driver for change, initiating, for example a discourse on payments for irrigation water. So far, however, strategic and participatory land use planning, including environmental and social impact assessments remain absent.

Key messages

All climate scenarios forecast prolonged dry periods. Overall, water demand will outweigh supply, calling for much more fair and adaptive allocation management. Further expansion of aquaculture into the reservoirs needs to be limited in order to maintain current trophic levels. More sustainable land management includes reducing stocking rates, maintaining vegetation structures and irrigation schemes that mimic as much as possible natural systems, which are able to regulate themselves.

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How to prevent the next global dust bowl. (Photo: KULUNDA)

KULUNDA – How to prevent the next "Global Dust Bowl"? – Ecological and Economic Strategies for SLM in the Russian Steppes: A Potential Solution to Climate Change

Background / regional context

The main goals of the interdisciplinary project KULUNDA were 1) to mitigate the degradation and desertification process, to stabilize and to enhance carbon sequestration in soils; 2) to increase crop yields through development and implementation of sustainable land management and 3) to contribute to rural and regional sustainable development.

The area of investigation was the Kulunda steppe in West Siberia, the largest fraction of the former virgin land region. Kulunda is composed of three different steppe types: forest, typical long grass and dry steppe. The climate is high continental. These steppes were subject to an extreme transformation of the natural landscape during the course of the Virgin Lands Campaign, aiming to achieve food security in post-war Soviet Union. The virgin land campaign led to a significant increase of agricultural land in a short period. The tillage intensity was very high; the soil was deeply ploughed in preparation for the crops. The highly intensive mechanical soil cultivation led to increased mineralisation of the soil and therefore to a decreasing humus content.

As a result 187,500 ha of arable land were destroyed annually during the Virgin land campaign by wind erosion and devastating dust storms. The Kulunda steppe belongs to the worst damaged areas. This is not better today: on the contrary, economic constraints, institutional uncertainties and rural outmigration impede the urgently required modernization of the agricultural sector. Although already in the 1960s attempts were made to respond to these environmental-economic problems, so far there has been no significant change towards more sustainable land use.

The project

In 2012 field trials started at three agricultural enterprises in the Altai district of the Kulunda steppe. These enterprises are located along a climatic and natural landscape gradient from the northeast to the southwest. The focus of the field trials was on tillage intensities in context of the regional water regime and soil fertility as both are the main factor for yield levels.

Crop rotation in the trial was a four-stage rotation with cereals, oilseeds and legumes. Three cropping systems were tested, a traditional (crop rotation including fallow land, intensive tillage, Soviet agricultural machinery) and an adapted Soviet system (no fallow, minimum tillage, Soviet agricultural machinery) as well as a Modern Canadian System (no fallow, no tillage, direct seeder).

Due to large plot sizes (0.7 and 1.4ha) the plots could be integrated into the running agricultural production process, allowing for active knowledge exchange between scientists and farmers. Dissemination of new methodologies and technologies took place during field days and vocational trainings in local institutes. Local media coverage contributed to a wider information and knowledge diffusion.

Major results

The presented field trials showed that the intensity of soil tillage and seeding technology used has a great influence on crop establishment and yield expectations. Extensive variants achieved higher water use efficiency, especially under no-till, stronger assimilation and higher yields. After 3 years only positive effects were also observed regarding soil structure and soil fertility. Minimized soil treatment led to higher aggregate stability, which results in lower risk of wind erosion, increased soil organic carbon storage and soil fertility as well as usable soil water content. However, problems remain: Adapting to this new technology requires training, but young potentially qualified staff so far does not return to the rural areas.

Methods and technologies supporting economically and ecologically sustainable as well as climate-optimised land use have been developed and tested. They, are now in initial use by local farmers. The methods principally are carefully adapted Soviet and Modern Canadian land management systems.

These adapted cultivation systems are more profitable, due to higher gross margins. In particular the Modern Canadian system allows to annually reduce production costs as for fertilizers and pesticides and makes room for investments in modern technology (as new land machines). This becomes an increasingly important factor as in the last four years prices especially for pesticides and fertilizers were strongly increasing. But: Especially due to the present state of unfinished land rights reforms, uncertainties for new credits and inadequate harvest insurances, farmers have limited capacities to invest in new machinery.

Key messages

- A sustainable agricultural use of steppes requires farming methods that minimize tillage intensity.
- Decreasing tillage intensities increase water storage capacity, minimize risk of soil erosion and stabilize soil fertility.
- The lower the intensity of tillage operation the higher the Soil Organic Carbon (SOC) sequestration rate.
- The tested adapted cultivation systems are more profitable and lead to an environmental benefit.
- Institutional, social and economic factors explain the diversity of land use intensity.
- Adapting to modern technologies requires better equipped and supportive extension services.
- The project results are an important contribution for the realization of the regional development programme “Altai Krai 2025”.

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Irrigated rice terraces, Vietnam. (Photo: LEGATO)

LEGATO – Rice Ecosystem Services
Land-use intensity and Ecological EnGineering – Assessment Tools for risks and Opportunities in irrigated rice based production systems

"We know how to grow rice in Asia, but the close cooperation with European partners within LEGATO opens up a new avenue of how to integrate landscape scale approaches for the improvement of our systems' sustainability." – K L Heong, IRRI/CABI

Background / regional context
LEGATO aims to advance long-term sustainable development of irrigated rice fields, against risks arising from multiple aspects of global change. The overall objective is the elaboration and testing of generally applicable principles within the frame of ecological engineering – an emerging discipline, concerned with design, monitoring and construction of ecosystems.

The project quantifies the dependence of ecosystem functions (ESF) and the services (ESS) they generate in agricultural systems in seven landscapes in Southeast Asia: Luzon island (Philippines): Laguna Province, Central-Luzon and Ifugao Province; Vietnam: Hai Duong Province, Vinh Phuc Province and Sapa area along the Red River Valley; and Tien Giang Province in the Mekong Delta.

The project
As core output, LEGATO develops guidelines for optimising ecosystem functions and services given the local sociocultural conditions and their stabilisation under future climate and land use change, which will particularly affect South and Southeast Asia. There is a clear need for crop productivity increases and diversification. LEGATO analysed the potential of ecological engineering to achieve this, and test its implementation and transferability across regions. The latter was achieved through inclusion of local agricultural agencies and extension services as partners. Implementation included assessments of ecosystem services risks and opportunities in the light of changes in land use intensity, biodiversity and climate.

One of the key problems in intensively managed irrigated rice production systems is the high pesticide use that can lead to health problems and severe decrease of biodiversity. Lower biodiversity can aggravate problems with pest outbreaks, because pesticides preferentially hit the more sensitive natural antagonists of pest species such as predatory spiders or parasitoid wasps, whereas major rice pest species such as plant hoppers often develop resistance against pesticides.

Ecological engineering aims to address this problem by providing habitats for natural antagonists of rice pests and thereby reducing the need for pesticide application. One technology of ecological engineering which was used by LEGATO and presented in this book is the planting of flower strips along rice field margins, which have the nice side effect of landscape beautification. However, this technology can only work successfully, if the whole farmer community of a region either stops using pesticides or only uses them in a very restrictive way as part of an integrated pest management (IPM) approach.

Convincing farmer communities to revert to more sustainable management practices requires effective communication and education, often against powerful lobbyism of the pesticide industry. One LEGATO approach shown in this book is the entertainment education approach, which uses mass media campaigns to spread the information among farmer communities.

Major results
First results of these approaches are encouraging, e.g. among farmer communities in South Vietnam, where ecological engineering techniques have been adopted especially by female members of the communities.

Although there is good evidence that more sustainable rice production will have substantial net benefits to farmers and biodiversity in the long term (win-win situation), possible short-term trade-offs and risks need to be taken into account.

Implementing ecological engineering as a dominant practice in irrigated rice production systems therefore requires continuous support of farmer communities using participatory approaches, as well as additional research, e.g. to identify the most suitable plant communities in different regions.

Key messages
- Ecological engineering is a promising approach for more sustainability in intensive rice production landscapes.
- Planting of flower strips around rice fields are an example of ecological engineering which increases biodiversity and provides habitats for natural antagonists of rice pest species, thereby reducing the need for pesticide use.
- Participatory approaches are needed to convince farmers to switch to more sustainable management practices.
- Initial successes have been achieved, but continuous support of farmers and additional research is required for long-term adoption of sustainable management practices.

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Traditional rice farming in Vietnam. (Photo: Michael Schultz)

LUCCi – From science to information for stakeholders – decision support for land and water management in a dynamic environment

Background / regional context

Land and water resources in South East Asia are under pressure due to rapid economic development, population growth, and changing climatic conditions. Vietnam with its long coastline belongs to the most vulnerable countries to climate change related hydrometeorological extremes and sea level rise. In the central Provinces Quang Nam and Da Nang, frequent drought events, floods and saltwater intrusion are strongly affecting socio-economic development, in particular agricultural production, urban water supply, infrastructure and the touristic sector. Traditional land use as large scale and subsistence rice farming is marginalized as demographic growth, urbanization and large-scale hydropower development are demanding more and more water and land resources.

On the other hand, Vietnamese forests and agricultural areas with their carbon storage capacities are increasingly recognized for their potentials for mitigation and adaptation to climate change. Within LUCCi German and Vietnamese scientists as well as international institutions analysed complex and dynamic systems to derive sustainable land and water management strategies for central Vietnam. Interdisciplinary research concepts and scenario development have addressed socio-economic development, national planning strategies, climate projections, GHG emission estimates and potential carbon sinks as well as the bio-physical environment and its ecosystem resilience.

The project

In order to develop sustainable resource management strategies, inter- and transdisciplinary research methods were applied. SLM practitioners dealing with agricultural land use, water management, hydropower, forestry and biodiversity from all planning levels including the national as well as the provincial, district and even communal level have been involved in all phases of the project:
Secondary data for climate, socio-economy, governance, land and water resources were collected and respective models have been set up. These data have been integrated into interlinked modelling approaches and results. Key system indicators and related research topics were determined in collaboration with the SLM practitioners. Scenarios were developed in order to test the sensitivity of the system components and as a knowledge base for the elaboration of land use strategies. The implementation phase started with the development of practice-oriented information in the form of figures, graphs, brochures and posters in Vietnamese and English.

Major results

The project highlights many options to increase water use efficiency in agriculture, decrease carbon emissions from land use and reduce saltwater intrusion. Results have been summarized by:

- The „VGTB-State of the Basin Report" supporting decision-making by providing a comprehensive overview on the bio-physical, institutional and socio-economic environment. Current dynamics, challenges and disaster risks are illustrated.
- Decision-support and recommendations communicated in policy briefs, posters and flyers, based on scenarios addressing land use changes, climate variability and change, socio-economic development, hydropower development, drought, salt water intrusion and flood risk, GHG emissions and carbon stock change.
- Open source database and information management platform: VGTB RBIS - River Basin Information System (VGTB - RBIS): http://leutra.geogr.uni-jena.de/vgtbRBIS/metadata/start.php.
- Vu Gia Thu Bon River Basin Information Centre (VGTB RBIC) offering: 1. Information on land uses, hydrology and river basin development in form of maps, figures, flyers and posters in Vietnamese language; 2. Organization of meetings and discussions providing a cross-sectoral communication space; 3. Training and capacity development services related to regional stakeholder demand.
- Along with workshops at the RBIC in Hanoi establishment of a network including stakeholders from the private and public sector, decision making, administration and researchers dealing with agricultural land use, water management, hydropower, forestry and biodiversity.

Key messages

- Make use of cross-sectoral decision-making in land and water resources management: e.g. jointly establish water allocation plans with representatives from the hydropower, irrigation, environment and public water supply sector.
- Foster cross-sectoral dialogue and communication among the involved actors from private and public sectors, decision-making, administration, research.
- Capacity building: Education is key to raise awareness about environmental issues and increasing resources conflicts. SLM practitioners and researchers need to be constantly trained. More capacity building programs for sustainable resources use and decision support systems need to be funded.
- In order to continue the process initiated with this project and to further transfer its results, collaboration between science and ODA institutions needs to be fostered. Joint funding programmes should be created to guarantee a long-term science-policy dialogue.

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Vast grasslands in Ishim region, Tyumen province, Russia. A landscape important for food production, biodiversity and climate mitigation. (Photo: Johannes Kamp)

"Future land use in Siberia has to consider a variety of uncertainties: climate, markets, policies and demographic trends. Achieving sustainable development will need to involve stakeholders of all sectors."

SASCHA – Sustainable land management and adaptation strategies to climate change for the Western Siberian Grain Belt

Background / regional context

The Russian province of Tyumen in Western Siberia is important for food production, climate change mitigation and biodiversity conservation. The massive peatlands and humus-rich steppe soils of the region have been recognised as carbon sinks of global significance. The region has been the scene of recent land-use change, including very widespread land abandonment following the break-up of the Soviet Union in 1991. More recently, these trends have been reversed. Recultivation and intensification of croplands were observed. Assets from the flourishing oil and gas industry of Western Siberia are now being reinvested into agriculture. Climate change could lead to an increasing drought risk and lead to northward shifts in agriculture. New expansion of cropland into fends and recultivation could lead to a release of greenhouse gases on a globally significant scale, with an important, but poorly understood potential for feedback mechanisms. Further ecosystem goods and services, such as water quality and soil fertility, are likely to be affected. Social systems will also be impacted by the fundamental changes in land-use and rural infrastructure. SASCHA aimed to provide basic knowledge, practical management tools and adaptation strategies to cope with recent and future land-use and climate change.

The project

There are few concepts and strategies in Western Siberia to steer and mitigate the fundamental land-use change and its implications for wildlife and society. SASCHA set out to provide baseline data on biodiversity and ecosystem services, to quantify and model ecological processes such as greenhouse gas fluxes, and to assess the impact of different land-use intensities. Remote-sensing tools allowing land users to monitor land use change were developed. Based on an evaluation of various scenarios, strategies for future sustainable land use were communicated to main stakeholders in farming and landscape planning. Farm trials implemented in collaboration with local farmers aimed at the development of farming techniques that increase resilience to climate change and make intensification processes less detrimental to biodiversity and ecosystem services. A wide array of local, regional and international stakeholders was identified and approached for collaboration. The socio-economic component of the project ensured realistic assessments and efficient targeting of the right audiences.

Major results

Land use change analysis revealed contrasting trends: a post-Soviet decrease, but more recent increase in land use intensity on arable land, and an ongoing decrease in management intensity of livestock systems. 600,000 ha cropland were abandoned during the 1990s in the province, and are slowly restoring back into natural systems. Biodiversity responses to abandonment were mixed, with many species benefitting from abandonment of arable fields, while vegetation succession on former pastures and hayfields impacted many specialised species negatively. Abandonment led to significant increases in soil organic carbon on former cropland, thereby partly mitigating global climate change impacts. Flux-measurements indicated that arable fields are CO_2 sources, whereas abandoned areas were sinks. Analysis of climate time series suggested an increase in growing days in the north of the province, and an increased drought risk in the south. This confirms anticipated regional shifts in suitability for agriculture. Hydrological processes are seasonally highly variable, suggesting the need for a fine-scale tuning of land management to avoid erosion. A scenario analysis with local stakeholders revealed that long-term sustainability is mainly driven by profitability levels in agriculture and state regulation. Sustainable land management can only be successful if decisions are advocated on very high federal levels, acknowledging the existing top-down decision-making. Successful collaboration and capacity building resulted in long-term perspectives of continued collaboration with researchers and practitioners in the region.

Key messages

- Future expansion and recultivation of cropland should be avoided as far as possible, as recently restored biodiversity and carbon stocks would be lost again, and greenhouse gas emissions increase.
- There is potential for "sustainable intensification" in agriculture. Yields can be increased through no-till management, which would also lead to higher resilience to drought and higher rural incomes. Improved manure management can reduce demand for mineral fertilizers.
- Subsistence livestock keeping by the rural population should be supported. Low-intensity grazing and haymaking also has a positive impact on biodiversity.
- Future sustainability in land use will depend on institutional sustainability, continued international collaboration and transnational policies.

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Market on the Mahafaly Plateau, Madagascar. (Photo: Jutta Hammer)

SuLaMa – Sustainable Land Management in south-western Madagascar

Background/ regional context

The Mahafaly region in Southwestern Madagascar is one of the most unique and biologically rich drylands on earth. Likewise, it is an extreme example of a fragile environment combined with extreme poverty and cultural constraints, resulting in huge land management problems. This makes research on sustainable land management particularly relevant in this area. The region needs to reconcile biodiversity conservation with sustainable land management strategies to improve food security for the rural human population in the face of global change. The conservation of the endemic forest ecosystem is essential, as regional development is constrained by unfavourable political and environmental conditions, making people heavily dependent on natural resources. Due to the low educational level in Madagascar, there is a special need for capacity building and knowledge transfer.

The project

The main objective of SuLaMa was participatory development and implementation of alternative land use practices to protect the ecosystem and its biodiversity, and to thus contribute to livelihood improvements of the local population in a sustainable manner.
Apart from developing land use alternatives, a central aim was to foster communication between and among stakeholders such as institutional authorities, technicians, researchers, and resource users. The project followed a participatory approach that allowed involving different stakeholders in integrated processes of planning, learning and decision-making. Participatory methods included baseline surveys, development of scenarios and modeling, feedback workshops with NGOs, GOs, communities and scientists, joint, experimental research and its implementation with local people, communication platforms and a joint product development with key stakeholder groups.

Major results

The collaboration with international, national and regional partners from the beginning was crucial for the project work. Together with farmers, rural communities, NGOs, universities and state agencies the project developed more than 30 products and measures to support sustainable land management. Key recommendations included improved techniques for sustainable crop and livestock fodder cultivation, the establishment of long-term community-based monitoring schemes, approaches for long-term data collection, integration and management, enhancing capacity building and knowledge transfer, and raising environmental awareness.

Apart from political insecurity, unpredictable weather events have become a major threat to people's well-being on the Mahafaly Plateau. In times of crop failure the local population has few alternatives to unsustainable use of natural forest resources. Thus, additional to the provided techniques and recommendations on sustainable land use, the promotion of alternative income sources and less risk-prone farming systems is a precondition for the long-term protection of the unique natural forest ecosystem of the Mahafaly Plateau.

A high level of acceptance of the project and its outcomes by the rural communities, which welcomed their integration and the participative project structure, increases the probability of independent implementation of project results by local communities.

Key messages

The intensity of the project's participatory approach and the close collaboration with different stakeholder groups were innovative aspects, which can serve as a model for future activities. The tandem-approach of German and Malagasy counterparts in all scientific disciplines (e.g. for writing PhDs) facilitated constant exchanges of perspectives and made research work easier for both sides.

The success of the project was mainly due to mutual trust between the local communities and the relatively long-term engagement of the scientists. Communication of results by non-scientific mediators was another key for understanding and acceptance.

Deeper understanding of the local culture as well as respect of indigenous knowledge is essential for successful implementation of alternative land use practices. Measures must fit people's livelihood requirements and cultural background. Especially when it comes to common-pool resources, sustainable natural resource management cannot be achieved without involving local individuals and communities.

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Vast grasslands in Ishim region, Tyumen province, Russia. A landscape important for food production, biodiversity and climate mitigation. (Photo: Patrick Keilholz)

SuMaRiO – Sustainable Management of River Oases along the Tarim River

Background / regional context

The Tarim River Basin is a large, unique and arid region of extreme vulnerability. The climate is continental with large temperature amplitudes, annually and daily. It is globally the most remote area from the oceans. Hence rainfall is extremely rare and low and does not exceed 50 mm per year. Thus, all kind of economic activities, especially agriculture and urban life, as well as the natural ecosystems depend on the river water as major water source. The Tarim River, the largest river of the Tarim Basin, is fed from snowmelt and glacier-melt in the upland mountains. Water discharge into the Tarim has been increasing over the last decade. However, global climate change prognoses forecast a shrinking water supply within this century. Due to strong extension of irrigated agriculture in oases along the rivers since the 1950s river flows have strongly decreased, leading to a degradation of floodplain vegetation, while agricultural soils have become unusable due to salinization. There is a clear trade-off between generating income from irrigation agriculture, mainly cotton, at the cost of ecosystem functions (ESF) and ecosystem services (ESS) provided by the natural ecosystems.

The central question is how to manage land use, i.e. irrigation agriculture and utilization of the natural ecosystems, and water use in a very water-scarce region, with changing water availability due to climate change, such that ecosystem services and economic benefits are maintained in better balance and a more sustainable development becomes feasible.

The project

In order to better understand the region and the processes related to water and land management, small case studies and projects were conducted in cooperation with the Chinese partners. Based on this fieldwork models have been designed and a large survey about socio-economic and environmental relations, the so-called Decision Support System (DSS) was developed. A software containing the DSS documents insights and helps to transfer them for the use of SLM-stakeholders and decision-makers in the region.

Since a large share of water is lost due to improper irrigation techniques, the application of drip irrigation under mulch is currently increasing. The already known principle of drip irrigation has been applied under plastic mulch, which minimized water loss due to less evaporation. In consequence, less water was needed and the salinization effect in the upper soil layers was decreased. Unfortunately, this method is spreading only slowly although beneficial effects have been evidenced by respective field experiments and water balance models.

Major results

With loss of overall amounts of water comes severe salinization and soil degradation. The endemic plant apocynum (Indian hemp) was revealing great potentials in terms of salt resistance and water demand. In addition, the cultivation of cotton is losing economic competitiveness and a substitution by Apocynum could by economically and ecologically favourable.

The project overall

- contributed to stronger awareness of the problems of water loss, salinization and soil degradation,
- developed optimized flooding schemes for the natural floodplains,
- supported better understanding of the groundwater recharge effects in the Tarim River Basin,
- showed an optimized approach for irrigation and drainage while minimizing salinization for agricultural land and soils,
- established a DSS for supporting decision-making and more sustainable land management.

Key messages

Slowing down of land degradation can only be achieved by more elaborated distribution of limited water resources. The two sources for irrigation water (1) groundwater and (2) river water need to be chosen more carefully and with more awareness of salinization effects. Already today measures are urgent to ensure appropriate recharge of groundwater resources, on which the natural vegetation strongly depends on. Only this way a long-term future for the region can be won.

With regard to ecosystem services and functions net costs for supporting sustainability are economically feasible as investments help to compensate negative land use effects.

Special attention needs to given to the arable land bordering the desert. These borders cannot be allowed to further reside. Ideally they are being extended back into degraded lands with successive gains of arable land and soils.

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Impressions from Xishuangbanna, south-west China. (Photos: Gerhard Langenberger)

SURUMER – Sustainable Rubber Cultivation in the Mekong Region

Background / regional context
Since the turn of the millennium, global production of natural rubber (NR) has increased by approximately 40% to more than 11 million tons per year. This increase has been predominantly driven by emerging markets, particularly China, which consumes more than 30% of the worlds NR production. The vast majority (approx. 90%) of NR production takes place in Southeast Asia. The Mekong River countries in particular have experienced an extraordinary rubber boom since 2000. Rubber plantations expand especially at the expense of natural forests of the "Indo-Burma biodiversity hotspot", one of the most outstanding global biodiversity hotspots. This development has serious impacts not only on people's livelihoods and socio-economic settings. It also affects provisioning of ecosystem services by compromising ecosystem functions at different spatial and temporal scales. Safeguarding these ecosystem functions requires a deep understanding of the complex processes driven by the current development. The overall objective of the SURUMER project, therefore, was to identify trade-offs and synergies between ecosystem functions and services on the one hand and socio-economic goals and constraints on the other, and thus to contribute to the development of integrated, user-friendly and stakeholder-validated concepts for sustainable rubber cultivation.

The project
The study area is located in the Dai Autonomous Prefecture of Xishuangbanna in Chinas Yunnan Province. The mountainous area borders Laos and Myanmar and is intersected by the upper Mekong River from north to south. The natural vegetation consists of tropical rain forest and seasonal monsoon forest of the Indo-Burma biodiversity hotspot.

SURUMER's research approach was based on inter- and transdisciplinary collaboration of nine scientific subprojects as well as SLM practitioners. To pursue the development of environmental friendly rubber management concepts, modifications in ecosystem processes due to the traditional practice but also socio-economic framework conditions needed to be identified and quantified.

To that purpose SURUMER conducted in-depth studies backstopped by stakeholder feedback. The consolidation of the resulting

"We know that there are somehow side effects [of the current land-use practices: authors´note] … However, SURUMER-researchers delivered the concrete data and results, which is of great importance for us"; „we were not aware of the serious side effects overuse of agro-chemicals could cause and will consider this now seriously" (farmers´ statements during stakeholder workshops recorded by J. Wang).

information required a high level of integration. This was facilitated by (a) inter-disciplinary and transdisciplinary communication and cooperation, (b) the integration of research results into the 'Land Use Change Impact Assessment Tool' (LUCIA) as well as modeling of different stakeholder approved scenarios. In the framework of the practical implementation of SURUMER's findings, alternative management options have been developed and demonstrated on test sites.

Major results
Via a stakeholder-driven design process the project (i) developed an ESS-assessment methodology that can be used to illustrate the effects, trade-offs and opportunity costs of decisions in land management based on scenario development and modeling; (ii) established case studies to demonstrate new potential pathways in sustainable rubber management; (iii) raised awareness of the importance of strategic land use planning on local as well as regional level; and (iv) addressed the needs of local / regional stakeholders.

SURUMER suggested concepts for ecologically and economically sustainable rubber cultivation at smallholder, plantation, but also landscape scale, the latter addressing in particular political stakeholders and decision-makers: innovative permanent tree intercropping, change of weeding scheme, establishment of water protection zones).

SURUMER further developed and enhanced the assessment tools "LUCIA" (Land Use Change Impact Assessment) and "InVEST" (Integrated Valuation of Ecosystem Services and Trade-offs), which are universally applicable and freely accessible.

Key messages
Natural rubber is a basic renewable resource, but it is not necessarily environmental friendly or sustainable. Farmers are aware of impacts like loss of biodiversity or degradation of soil and water quality. Additionally, the reliance on one product with high price volatility and its cultivation beyond its adaption zone was shown to be highly risky. Farmers were willing to improve the management but lack the capacity and funding to realize innovative measures. Therefore, capacity building is indispensable and needs to be associated with stakeholder-focussed expert support.

Transferring scientific concepts into practical land use is only feasible if relevant stakeholders at various levels are involved during the entire conceptualization process, ranging from a joint definition of project goals to the evaluation of the concepts, in particular the joint assessment of trade-offs through alternative land-use scenarios.

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Conventional land management in the Okavango Basin. (Photo: Rasmus Revermann)

TFO – The Future Okavango

Background / regional context

The Okavango Basin in South-West Africa transgressing Angola, Botswana and Namibia is presently turning into a hot-spot of accelerating commercialization, land-use change and potential land-use conflicts. Predominantly rural people in this region practise rain-fed subsistence agriculture, the main livelihood for at least 1,000,000 people. This growing population is largely poor, and most of its members use savannas and wetlands to secure their well-being on communal territories. Multiple uses of ecosystem services (ESS) such as crops, fish, wildlife, fuel, timber, fibre, forage, and water to meet the basic needs of energy, food, and water supply are potentially transforming ecosystems through overutilization and commodification, with unknown consequences for the ecosystems and local livelihoods.

The project

TFO has sought to generate scientific knowledge to support an integrated transboundary management for the Okavango region that allows for a more sustainable and equitable utilization of its ecosystem services. To reach this objective, the project has investigated fundamental ecosystem processes and functions as well as ecosystem services, ranging from tangible goods such as food and timber to intangible benefits, such as the spiritual values of the environment. The goal was first to provide an assessment of the current status of the ecosystems and their services. A second, equally important task was to understand how SLM practitioners at different levels (the land users and land managers) value and actively involve these services in their daily strategic actions as well as their future plans. Thirdly, TFO developed scenarios for the future illustrating alternative pathways that current land-use dynamics, population trends and management plans might follow.

Major results

TFO has provided a status analysis and key findings. We found that the system and its diverse landscapes are still largely intact. However, rapid increase of human activities like slash-and-burn agriculture, road construction, and agro-industrial intensification clearly drive the fragmentation of ecosystems. Three main processes of transformation and degradation have been identified: 1) poverty-driven smallholder subsistence agriculture penetrating into the hinterlands of the rivers and patchily transforming and degrading the ecosystems, 2) the intensification and commodification of the production of firewood, timber, charcoal, thatch, bushmeat, honey and other ecosystem goods, and 3) the investment-driven implementation of large agro-industrial schemes. The currently performed smallholder subsistence forms of agriculture are not efficient and result in soil degradation and reduced yields, thus potentially causing households to fall into a poverty trap. Consequently rural systems and societies are on a pathway towards impoverishment and natural resource degradation. Therefore, considerable but sustainable productivity improvements in the agricultural systems are a must for the future. We found significant potential for improving the governance of the system that needs to develop more equitable, effective, and inclusive water- and land-related policies and strategies.

Key messages

- Transboundary planning on water utilization must take the fundamental differences of the dominant hydrological processes of both sub-basins (Cubango and Cuito) and their intra-annual contribution to the Okavango Delta inflow into account.
- An integrated conservation and land-use planning concept is urgently needed. TFO has presented suggestions regarding nature reserves, securing of ecosystem- and migration-route connectivity, buffering functions of wetlands, and the important role of woodlands for livelihoods and a functioning water flow regime. Protective measures on the local scale should engage communities and prioritize advocacy, rather than regulation.
- The trade-off and potential conflict between the values generated by woodlands vs. the values generated by crop production needs further attention.
- TFO mapped the high frequency of bush fires in the basin with their detrimental effects on animals, losses of nutrients (especially nitrogen), and the regeneration potential of woodlands. Reducing and managing the frequency of human-induced fires should be of high priority.
- As crop production by smallholders will likely remain the backbone of rural livelihoods within the Okavango Basin a shift in development paradigms is needed. Future campaigns should focus on increasing yields on existing dryland plots by encouraging the use of alternative technologies such as conservation agriculture.
- Complex linkages between ecology and society have been identified which shape peoples values and influence peoples decisions and actions upon ecosystem services. Such interactions are embedded in rapid global transformation processes and need to be considered in societal discourses and by decision-makers.

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Glossary of terms

Agricides: Agro-chemicals including herbicides, pesticides, fungicides etc.

Agrobiodiversity: A term used to describe biodiversity associated with the cultivation of crops and rearing of animals. There are three elements to agrobiodiversity (a) the overall range of different crops and animals (b) the diversity of crops and animals within a particular farming systems and (c) the overall biodiversity of both cultivated and natural species within a farming system. Sustainable land management can help maintain and build up levels of biodiversity in all ecosystems.

Approaches/ Questionnaire Approach (QA)[1]: An SLM Approach defines the ways and means used to implement one or several SLM Technologies. It includes technical and material support, involvement and roles of different stakeholders, etc. An Approach can refer to a project/ programme or to activities initiated by land users themselves. QA addresses the questions of how implementation was achieved (including capacity building, decision-making, technical and material support, change of legal framework and policies) and who achieved it (including all stakeholders involved and their roles).

Biome: The largest unit of ecological classification that can be described below the entire globe. It describes the formation of plants and animals with common characteristics within a similar climate. Terrestrial biomes are typically based on dominant vegetation structure (e.g. forest, grassland).

Black fallow: A fallow period or method, usually as a part of crop rotation, without soil cover – so that the 'black soil' is lying bare.
Brownfields: Unused areas within cities, often previously used for industrial or other commercial purposes.

Business-as-usual (BAU): A term used in scenario development to describe a scenario in which the current policy or management is continued without changes. It sometimes is also called 'Trend' referring to a continued development of the current development trend.

***Caatinga* woodlands:** Dry forest and shrubland vegetation typical in an area in Northeast Brazil, in the Pernambuco part of the São Francisco River Basin.

Carbon sequestration: The process of increasing the carbon content of a reservoir (e.g. water or soil) by extracting CO2 from the atmosphere.

***Cerrado*:** Tropical savannah region in South-eastern Brazil, covering parts of the states: Goiás, Mato Grosso do Sul, Mato Grosso, Tocantins and Minas Gerais. It includes forest savannah, wooded savannah, park savannah, gramineous-woody savannah, savannah wetlands, and gallery forests.

Climate-Smart Agriculture (CSA): Agricultural practices that sustainably increase productivity and income of farm households, adapting and building resilience of the agricultural system to climate change, while reducing greenhouse gas emissions and/or sequester carbon.

CO_2 equivalent: A quantity to describe the impact of different greenhouse gases on the climate sometimes also called 'global warming potential'. It stands for the amount of CO2 that would have the same impact as the greenhouse gas (methane, nitrous oxide, ozone etc.) measured over a specific time (usually based on 100 years). It is used to compare different greenhouse gases and assess the impact of different management options with an overall value.

De-embankment: A practice of opening low-lying areas in coastal zones to the influence of seawater by opening or removing seawalls; also sometimes called "realignment".

Drip irrigation: A method of irrigation to increase water use efficiency compared to sprinkler or flood irrigation. The irrigation water is provided onto the soil surface at the base of the plants or directly at the plants root zone through a network of valves, pipes, tubing, and emitters by dripping water. The method especially reduces water loss through evaporation.

Eco-engineering/ ecological engineering: Design, monitoring and construction of ecosystems to enhance/ maximize ecosystem services - in the context of this book e.g. enhancing crop productivity through higher landscape and functional diversity, or stabilizing food-web structures for pollinators and to support ecological pest control.

Ecological intensification: Management practices that make better use of an ecosystems full potential, e.g. for food production, while maintaining or improving the ecosystems functions and services and minimizing trade-offs between different ecosystem services. These practices have been developed as an alternative to intensification practices that are dependent on high inputs of agrochemicals (fertilizer, pesticides etc.) to produce high yields, and cause damage of the ecosystems and decrease their services.

Ecosystem function (ESF): An intrinsic characteristic of an ecosystem related to the set of conditions and processes through which an ecosystem maintains its integrity (such as primary productivity, food chain, biochemical cycles). According to the framework of the Millennium Ecosystem Assessment[2] ecosystems functions include such processes as decomposition, production, nutrient cycling, and fluxes of nutrients and energy.

Ecosystem services (ESS): The benefits people obtain from ecosystems. According to the framework of the Millennium Ecosystem Assessment[2] these services are categorized into (a) provisioning services such as food and water, (b) regulating services such as flood and disease control, (c) cultural services such as spiritual, recreational and cultural benefits, and (d) supporting services such as nutrient cycling that maintain the conditions of life in Earth.

Extensification: The process of decreasing the intensity of agricultural land use, e.g. including a fallow period in the crop rotation, decreasing the number of animals grazing on an area of grassland. Extensification is usually used to improve natural biodiversity and ecosystem health within agricultural systems and sometimes compensated through public payments.

Farmer field school: A method of educating farmers by regularly gathering them on one of their owns fields and learn jointly and from each other about agricultural practices. Techniques are observing, analysing and experimenting, often facilitated by a professional trainer. The method was developed as and alternative to the typical top-down approaches of extension services during the 'Green Revolution'.

Flood retreat agriculture: Flood recession agriculture using plants and crops growing along rivers, their tributaries and deltas, ephemeral riverbeds and around lakes to profit from flooding (opportunistic irrigation) and make use of residual moisture after flood retreat.

Greenhouse gas(es) (GHG): A gas in the atmosphere that contributes to the greenhouse gas effect by absorbing infrared radiation. This radiation is produced by the warming of the earths surface by the sun. The primary greenhouse gases in Earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide, and ozone.

Green manure: A crop, such as clover and other nitrogen-fixing plants, ploughed under to enrich the soil (improve organic matter content and soil fertility).

Humus: A part of soil organic matter that forms in the soil when plant and animal matter decays. It contains many useful nutrients for healthy soils and is the basis for natural soil formation. It can also be produced artificially using plant and food residue and then applied to amend soils.

Landscape mosaic: The pattern of landscape elements (patches, corridors, matrix). Often used to describe diverse landscapes combining elements of used/ managed and natural/ semi-natural land.
Micro-spray irrigation: A variation of drip irrigation that uses devices called micro-spray heads, which spray water in a small area, instead of dripping emitters.

Participatory rural appraisal (PRA): A research and planning method to engage people from a local community in an assessment of their resources, problems, and possible solutions. It consists of a set of mostly visual techniques, strives to represent the multiple perspectives within a community, and makes use of local knowledge.

Payments for ecosystem services (PES): Compensations or incentives paid to land owners or land managers in exchange for the enhancement or maintenance of ecosystem services (e.g. clean water, biodiversity habitats, carbon sequestration capabilities) that would otherwise be decreased or threatened. These can be public payments to land owners, market trading schemes as well as self-organized private deals.

Perched aquifer: An aquifer found closer to the surface that the main water table due to a localized impermeable layer in the soil.
Polder: A low-lying area of land enclosed by seawalls and/or dams. It is either drained for agricultural use or used as a retention area for surplus water with a water level above ground and respective vegetation, esp. reed.

REDD+ (or REDD-plus): Acronym for "reducing emissions from deforestation and forest degradation". This mechanism is negotiated under the UN climate convention (UNFCCC) since 2005. It aims at mitigating climate change through more sustainable forest management (including forest conservation and enhancement of forest carbon stocks) in developing countries. Through financial incentives the carbon stocks stored in forests should be given economic value.

Resilience (e.g. climate): This term basically stands for the ability of a system to cope with change. In a global change context it is the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance by responding or reorganizing in ways that maintain their essential function, identity, structure, and feedbacks. The systems also need to maintain their capacity for adaptation, learning, and transformation in the face of oncoming changes.

Riparian forest: A riparian forest or riparian woodland is a forested or wooded area of land adjacent to a body of water such as a river, stream, pond, lake, marshland, estuary, canal, sink or reservoir. These forests are often buffer zones between managed land an water bodies and play important roles for groundwater recharge, water filtration and quality, prevention of river bank erosion, and sediment control.

Stakeholder: In the context of this book we use the term 'stakeholders' to refer to people involved in or impacted by land management, such as representatives from associations and local initiatives, indigenous people, local/regional/national government representatives and their agencies, private enterprises/ business representatives, as well as many individual land users and land owners, and the researchers working in the involved research projects.

Sustainable land management (SLM): Sustainable Land Management (SLM) in the context of WOCAT[3] is defined as the use of land resources – including soils, water, vegetation, and animals – to produce goods and provide services to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions.

Technologies/ Questionnaire Technology (QT)[1]: An SLM Technology is a physical practice on the land that controls land degradation, enhances productivity, and/or other ecosystem services. A Technology consists of one or several measures, such as agronomic, vegetative, structural, and management measures. QT helps to describe and understand the land management practice by addressing the following questions: what are the specifications of the Technology, what are the inputs and costs, where is it used (natural and human environment), and what impact does it have?

Watershed (also drainage basin, catchment basin, river basin): A watershed is a topographically limited area from which all water is drained by a common water course/ outlet, or in other words the area with a common water flow or drainage system joining in one body of water such as a river, lake, reservoir, estuary, wetland, sea or ocean.

[1] https://www.wocat.net/en/methods/slm-technologies-approaches/questionnaires.html
[2] http://www.millenniumassessment.org/documents/document.776.aspx.pdf
[3] www.wocat.net

List of abbreviations

ANA Hydroweb	Agência Nacional de Águas, Brazil; http://hidroweb.ana.gov.br/
a.s.l.	above sea level
BMBF	Federal Ministry of Education and Research, Germany; Bundesministerium für Bildung und Forschung; https://www.bmbf.de/en/index.html
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Germany; Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit; http://www.bmub.bund.de/en/
C/ CO_2	Carbon/ Carbon dioxide
CABI	Centre for Agriculture and Biosciences International; http://www.cabi.org/
CBD	Convention on Biological Diversity; https://www.cbd.int/
CBHSF	Comitê da Bacia Hidrográfica do Rio São Francisco - São Francisco River Basin Committee; http://cbhsaofrancisco.org.br/;
CBM	Community Based Monitoring
CC	Climate Change
CESR	Centre for Environmental Systems Research, an interdisciplinary research institute of the University of Kassel, https://www.uni-kassel.de/einrichtungen/en/cesr/home.html
CKB	Climate Knowledge Brokers Group; http://www.climateknowledgebrokers.net/.
CPRM	Serviço Geologico do Brasil; http://www.cprm.gov.br/
CSA	Climate Smart Agriculture; http://www.fao.org/climate-smart-agriculture/en/
DSS	Decision Support System
EC-EARTH	Combines the atmospheric circulation model IFS (ECMWF) with the ocean model NEMO, including sea ice (LIM2) and land surface (HTESSEL) components https://www.ec-earth.org/
ECHAM	Atmospheric general circulation model http://www.mpimet.mpg.de/en/science/models/echam/
Eco-DRR/ EbA	Ecosystem-based Disaster Risk Reduction/ Ecosystem-based Adaptation
ESF/ ESS	Ecosystem Functions/ Ecosystem Services
FAO	Food and Agriculture Organization of the United Nations; http://www.fao.org/home/en/
FONA	Development (FONA) is the BMBF platform for research for sustainable land management; https://www.fona.de/en/ Research for Sustainable
GHG	Green House Gases
GEF	Global Environment Facility; https://www.thegef.org
GIS	Geographical Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GmbH); https://www.giz.de/de/html/index.html
IFAD	International Fund for Agricultural Development; https://www.ifad.org
INCRA	National Institute for Colonization and Agrarian Reform; Instituto Nacional de Colonização e Reforma Agrária; http://www.incra.gov.br/
IRRI	International Rice Research Institute; Philippines; http://irri.org/
KBF	Knowledge Brokers' Forum; http://www.knowledgebrokersforum.org/)
LPJmL	Lund-Potsdam-Jena managed Land Dynamic Global Vegetation Model; https://www.pik-potsdam.de/research/projects/activities/biosphere-water-modelling/lpjml;
LULCC	Land Use and Land Cover Changes
MAgPIE	Model of Agricultural Production and its Impact on the Environment
MaxEnt	Maximum Entropy biodiversity model
M&E	Monitoring and Evaluation
MIKE SHE	MIKE Système Hydrologique Européen
MMA	Ministério do Meio Ambiente, Brazil; http://www.mma.gov.br/
MODIS terra	Moderate Resolution Imaging Spectroradiometer on NASA's Terra satellite

MOIT	Ministry of Industry and Trade Vietnam; http://www.moit.gov.vn/en/Pages/default.aspx
MONRE	Ministry of Natural Resources and Environment, Vietnam; http://www.monre.gov.vn/wps/portal/english
Moneris	MOdelling Nutrient Emissions in RIver Systems
MRV system	Measuring, Reporting and Verifying system
OKACOM	A Comissão Permanente das Águas da Bacia Hidrográfica do Rio Okavango - The Permanent Okavango River Basin Water Commission; http://www.okacom.org/
PES	Payment for Ecosystem Services
QA/ A	Questionnaire on Approaches, Approach https://www.wocat.net/en/methods/slm-technologies-approaches/questionnaires.html
QT/ T	Questionnaire on Technologies, Technology https://www.wocat.net/en/methods/slm-technologies-approaches/questionnaires.html
R&D	Research and Development
REDD+	REDD-plus: 'reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries'
REMO climate model	Regional Modelling of present and future climate http://www.remo-rcm.de/
RBIC/ RBIS	River Basin Information Centre/ River Basin Information System, Vietnam
SDGs	Sustainable Development Goals; http://www.un.org/sustainabledevelopment/sustainable-development-goals/
SIRGAS 2000	Sistema de Referência Geocêntrico para as Américas; GeoRepository http://www.sirgas.org/index.php?id=77
SLM	Sustainable Land Management
SOC/ SOM	Soil Organic Carbon/ Soil Organic Matter
SOS GIS Brazil	https://sosgisbr.com/
SRES	Special Report on Emissions Scenarios; http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=0; https://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf
STAR/ CCLM	STatistical Analogue Resampling Scheme/ Climate Limited-area Modelling-Community (CLM-Community)
SWAT	Soil and Water Assessment Tool; https://en.wikipedia.org/wiki/SWAT_model.
SWIM	Soil and Water Integrated Model
SWOT	Strengths, Weaknesses, Opportunities and Threats analysis framework
Telemac	Telemac hydrodynamic model; www.opentelemac.org/
TgC	teragram carbon
TWh	terawatt hours
UBA	'Umweltbundesamt'; https://www.umweltbundesamt.de/en
UNCCD	United Nation Convention to Combat Desertification; http://www.unccd.int/en/Pages/default.aspx
UNFCCC	United Nations Framework Convention on Climate Change; http://newsroom.unfccc.int/about/
USD	United States Dollar
VGTB	Vu Gia Thu Bon (River Basin), Vietnam
WOCAT	World Overview for Conservation Approaches and Technologies; https://www.wocat.net/en/
WWF	World Wildlife Fund; http://www.worldwildlife.org/

SUSTAINABLE LAND MANAGEMENT
GLUES

LEGATO
RICE ECOSYSTEM SERVICES

Carbiocial

CC-LandStraD
Climate Change – Land Use Strategies

SASCHA

LUCCi Land Use and Climate Change Interactions in Central Vietnam

SuMaRiO

SURUMER

TFO
THE FUTURE OKAVANGO

SuLaMa

INNOVATE

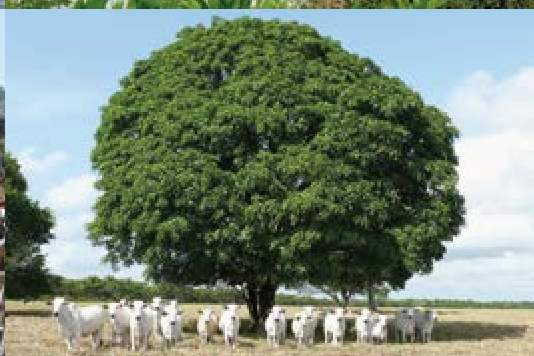
COMTESS

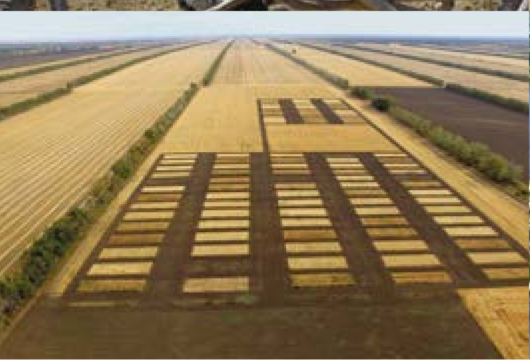
KULUNDA









WOCAT

peter moll & ute zander

SUSTAINABLE LAND MANAGEMENT GLUES

UNCCD United Nations Convention to Combat Desertification

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