Science to put sustainable land management into practice

Key insights from a seven-year global research programme

Helmholtz Centre for Environmental Research – UFZ

Sustainable land management (SLM) is on the highest of global agendas. The UN Convention to Combat Desertification (UNCCD), for example, is now prioritizing sustainable development goal (SDG) number 15 – Life on Land. That is just one of seven in all the 17 SDGs and other global priorities that need SLM.

Pressures on the world's land are clearly mounting. Increasing consumption and growing population are placing a complex demand on food supply, and climate change has become an urgent stressor. Can we respond with a more sustainable use of precious land resources? Is it possible for agriculture to gain higher, more reliable yields – and yet do so responsibly? Under the five themes of food security, water management, climate change, biodiversity conservation and ecosystem services, this policy brief summarizes the highlights of seven years of research to deliver some answers – with practical solutions for global and local challenges in land use.

Making the scientific understanding of sustainable land management usable in the field, this scientific synthesis project, GLUES, coordinated by the Helmholtz Centre for Environmental Research – UFZ, was part of a research programme on SLM funded by Germany's Federal Ministry of Education and Research – BMBF. The insights here will enable policymakers and others to support SLM as a vital contribution to global problems. Now more than ever, lessons about the interactions between land use and socioeconomic, cultural, environmental and climate factors are of crucial importance.

Experimental field sites in Western Siberia. See Research insight: KULUNDA. Photograph: A. Kozhanov

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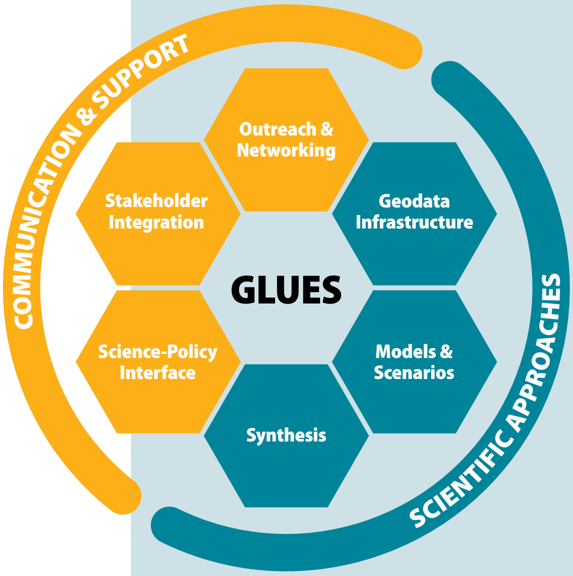

What was GLUES?

GLUES was a scientific coordination and synthesis project supporting the sustainable land management research programme of Germany's Federal Ministry of Education and Research. The abbreviation comes from the full name, Global assessment of land use dynamics, greenhouse gas emissions and ecosystem services. The core team at the Helmholtz Centre for Environmental Research – UFZ coordinated and synthesized the international research findings involving some 500 scientists from 12 regional projects around the globe.

Lessons from the research can be transferred to other regions around the world, offering a better understanding of the interactions between land-use intensity, socioeconomic conditions, ecosystem services, biodiversity and climate.

Photograph: A. Künzelmann

Food security

Number two in the list of UN sustainable development goals is Zero Hunger, and while population growth is projected to continue at a slower rate, demand for food by 2050 will nonetheless have risen twofold compared with recent years.[1] A study published in *Ecology and Society*[2] in 2014 shows from recent data that the limits for the production of many renewable sources are approaching. Prof. Dr Ralf Seppelt, leader of the GLUES programme and main author of that paper, says the answer to this is not in uncontrolled land use for food. "A balance can be reached," he says, "by farmers intensifying production on environmentally sound land, foodstuffs being better distributed around the globe and people changing their eating habits and throwing less away." To reiterate this, in addition to SLM insights (below), also important for our food security is better distribution and access to food, less waste, and 'closing the diet gap' through changed consumption patterns.

Key insights and recommendations for food security

Rather than feeding the demands of a growing, wealthier world population through the expansion of land exploitation, global agricultural yield could be boosted sufficiently from the land already in use. GLUES research published in *Nature Communications*[1] finds investment in better management of current cropland will have "a larger potential for achieving food security than previous studies have indicated".

In tropical regions of Africa and Latin America, for example, more cropping intensity will be an important driver of higher production. "Several regions in China and South America also show increased production potentials through a reallocation of crops towards more profitable locations," suggests Prof. Mauser, the lead author of the study, and such moves will avoid the greater loss of biodiversity and higher releases of greenhouse gases brought by expanded farmlands.

Further insights for the world's diverse food security problems come from the stories of the projects in this research programme as well as the science closely bound to them. It is the science that makes many of the lessons transferable around the world, but also the policy.

Fragile human populations in equally fragile habitats

In the SuLaMa project in Madagascar, the unique human factors and environmental conditions in the south-west of the island nation are characterized by poverty and drought, where people survive directly off the land, seasonally moving across the Mahafaly plateau with their livestock.

1 Mauser W et al, Global biomass production potentials exceed expected future demand without the need for cropland expansion, *Nature Communications*, doi: 10.1038/ncomms9946.

2 Seppelt R et al, Synchronized peak-rate years of global resources use, *Ecology and Society*, doi: 10.5751/ES-07039-190450.

West-Siberian agriculture: vast plains of land are vulnerable to wind erosion. Photograph: M. Frühauf

Research insight: KULUNDA

Preventing a global dust bowl while improving food security

Wind erosion and poor soil quality mean that up to half the agricultural land in the semiarid region of Kulunda is degraded.

During the Virgin Lands campaign (1953–1960), this region in south-west Siberia saw widespread extension of cultivated land: in 1954 alone, 2.5 million hectares were ploughed up. The Kulunda steppe, which receives less than 350 mm of annual rainfall, is therefore vulnerable. There is the high risk of wind erosion and the potential for a new 'dust bowl' event, similar to that of the 1930s in the great plains of the Middle-West of North America. Extreme dust storms there led to massive ecological problems that included yield losses, and major human displacement.

The traditional Soviet cropping systems in Kulunda have been based on intensive soil tillage. The resulting vulnerability is from various factors, including degraded soil structure and aggregate stability, low soil organic carbon, and poor soil cover. Urgently needed practices include minimized soil treatment, and permanent covering. This will protect and improve the land – and also help to mitigate climate change.

Further, the project's field trials have shown that crop yields can also rise. In one study,[3] wheat seeding without conventional ploughing over three seasons lifted the soil moisture by 42% and the grain yield by 11.3% – and cut the costs of fuel and labour by up to 80%.

The KULUNDA project was led by Martin-Luther-University Halle-Wittenberg.

3 Kühling I and Trautz D, Climate smart agriculture in Western Siberia – potential of no-till in spring wheat production, http://tinyurl.com/y7rw5f72.

- Madagascar's forest products of wild yam, medicinal plants and tamarind are important not just to food security but socially and culturally, too – yet population and economic pressures have led to overuse.
- Tamarinds, formerly treated with great reverence as spiritually sacred trees, have been exploited for charcoal.
- Social scientists working with the SuLaMa research team have played a part in recommending solutions. These include raising awareness of sustainable approaches to yam cultivation and harvesting, and using alternatives to tamarind for charcoal or developing village plantations for the tree.

The SuLaMa region is also an example to follow for vegetable production in home gardens as a feasible diversification strategy for food security. This strategy can be improved by including trees and shrubs and by alley cropping. Agroforestry systems with drought-tolerant crops are another example, using millet and sorghum instead of maize.

Crop solutions with water benefits

In the semi-arid areas of Africa studied by the TFO (The Future Okavango) project, crop production on deep sands was at risk of failure because of dependence on seasonal rainfall amounts and patterns, and an overreliance on irrigation.

- Woodlands are better adapted thanks to their deep rooting systems, taking up water from deep layers in dry spells and preventing the leaching of nutrients.
- The potential food security benefits are in addition to the water management ones – because the strategy also has less water demand. For TFO, this reduced the threats downstream to the Okavango Delta.

Adaptive practices and sustainable intensification

Finally, food security recommendations can be drawn from the adaptive management practices that have lifted yields in the Kulunda steppe (see Research insight: KULUNDA), and the sustainable intensification championed earlier by Prof. Seppelt is amenable to various world regions that may take the opportunity to increase yields.

Water management

The vital importance for human wellbeing of clean water is obvious, and the UN spells out the priority – sustainable development goal number six is to "ensure availability and sustainable management of water and sanitation for all". But the critical part of that goal is *sustainable management*: exploitation of water resources for agricultural irrigation and food security, direct human consumption and other rising demands must be balanced against protecting our environment's water systems. Climate change and extremes add to the water stress and create a need to respond both to too little water and to too much, often dealing with each in the same place at different times. Drought and flood events focus the need to adapt our land use and to increase, for example, the efficiency of rainwater use.

Key insights and recommendations for water management

Two of the projects with particular relevance to sustainable water management have been highlighted in this policy brief (see the Research insights: INNOVATE and LEGATO). Many more examples concerning irrigated agriculture – which accounts for over two-thirds of the world's water withdrawal – will need to follow these sorts of lessons for tackling water scarcity. Water scarcity is not an isolated challenge; severe expansion of soil salinization also results from overirrigation. Various water interests, not just agriculture, are in conflict, too, including industrial and domestic ones such as hydropower generation.

Itaparica reservoir seen from Petrolândia town. Photograph: V. Rodorff

Research insight: INNOVATE

Lessons for large dam reservoirs

Securing electricity, improving local people's lives and tackling poverty were important factors for creating the Itaparica Reservoir. An ambitious project, some 40,000 people had to be relocated when the São Francisco River in Brazil was dammed in the late 1980s. "The consequences of the dam for the local people and the landscape were not," however, "thought through properly," says INNOVATE project head Prof. Dr Johann Köppel. Yet insights from the experiences of Itaparica, and the team's scientific work to make recommendations, provide answers on a number of globally relevant challenges. Take climate change as one example: this makes it increasingly difficult to meet all the needs demanded of water from large rivers like São Francisco. Water for hydropower changes lives, and, drawn sustainably, plays an important part in cutting dependence on fossil fuels. But water sources are of course not endless, and they are changing. Also, as evermore is used for irrigation, drinking and other needs, simultaneous supply for hydropower is reduced.

Through modelling expertise, the INNOVATE team led by Prof. Köppel found that switching to solar and wind energy was a feasible way to diversify the energy supply in the great Brazilian river basin – thanks to environmental and policy conditions being favourable. Such places with existing dams also come with suitable power infrastructure already in place. Finally, the wider project in the São Francisco River Basin yields other water management insights from recommendations, for example, to minimize daily water fluctuations using clever, ecologically responsive irrigation pumping. Transferable examples from this project are also found in the recommendations to help prevent toxic algal blooms in the reservoir.

The INNOVATE project was led by Technische Universität Berlin.

Conserve and store water

The leading SLM principle against water scarcity and the high investment costs of irrigation is to make the most efficient use of rainwater, and to conserve water, thereby cutting the demand on irrigating sources.

In arid and semi-arid environments especially there is still great potential for more water harvesting and storage. Strong management skills need to accompany SLM solutions. Decision-makers must balance multiple demands placed on reservoir water especially. There must be balance between pressures for hydropower, irrigation and ecological flow.

Improve irrigation efficiency

For land management large and small, the conservation of water within irrigation practices relies on the following examples as key principles:

- Sprinklers or even drip irrigation in place of flood irrigation, along with improved timing;
- Crop choices that are drought-resistant, drought-tolerant or water-efficient;
- Irrigation adapted to local soil and water conditions, for example to tackle salinization;
- Water quotas and pricing to compel more efficient water use.

Climate change

Climate change and land management have a two-way coupling. Climate change puts pressure on land management, and land use is responsible for 20–40% of current greenhouse gas emissions. By seeing land use as both a subject of the effects of climate change and a contributor to it, SLM means addressing both.

Choices for the use of land, and for the management of soil, water, vegetation and animals, can either create a net carbon source, or a net carbon sink. To help achieve UN sustainable development goal number 13 ("take urgent action to combat climate change and its impacts"), land management can be targeted at lower emissions of greenhouse gases and at protecting carbon sinks, or even sequestering more carbon into the land or biomass.

Under climate change, all species are affected by changing rainfall patterns, increases in ambient CO_2 levels, and higher temperatures, such as through effects on species distribution and productivity. Yet efforts to mitigate climate change impacts and to help reduce CO_2 are not fast-acting, so land users often face compromises for the promise of slow-to-emerge benefits, or for the avoidance of predicted harms – so science and policy that engages with these challenges is important.

Nelore cattle, pictured here in an Amazon region of Brazil, are well adapted to tropical climates. But to make way for cattle – and for soya, maize and cotton crops – rainforests have been cleared and the timber sold, degrading a vital forest for carbon-capture and storage. Photograph: Stefan Hohnwald

Key insights and recommendations on climate change

Reduce emissions and protect and increase carbon storage

Lessening the contribution to climate change from emissions caused by land use and intensive cultivation can be achieved by:

- Sustainably intensifying production on land already in use, and so sparing lands that have a higher carbon-storage potential from being converted in agricultural expansion (reversal of such land conversion was seen in the TFO project);
- Avoiding or reducing major changes in land use such as deforestation, rapid urbanization and erratic urban sprawl (part of Germany's sustainable development strategy, for example, is to reduce conversion of land into settlement and transportation);
- Protecting wetlands and grasslands from conversion;
- Improving production systems responsible for high greenhouse gas release.

Long-term investment is needed to counter greenhouse gas emissions, causes of which include the following land-management factors:

- Unsustainably intensified use, which disturbs soil, reduces aggregate stability, leads to a loss of soil organic carbon (which also means a loss of fertility), and leads to a loss of vegetation and soil cover;
- Change in use that results in a lower potential for carbon storage.

To protect the existing carbon storage provided by soils with a high carbon stock:

- Avoid excessive drainage – which causes oxidation and subsequent mineralization of organic soils – and keep groundwater levels at an optimal depth;
- Provide permanent soil cover and avoid agronomic practices and production systems that accelerate soil erosion, replacing them with minimal ploughing or even no tillage at all (as in Research insight: KULUNDA, which answers food security, too);
- Avoid clearance of bush or forest.

Enhance carbon sequestration

Improved management of mineral soils through better cover and less soil disturbance can improve carbon stocks without having to increase groundwater levels. The carbon sink can be bolstered even further with high water levels – but there is also a complex relationship in terms of carbon sequestration versus methane (CH_4) emission in the first years after, for example, re-wetting organic soils, because of an effect against CH_4-consuming bacteria.

Rewetting of organic soils to reverse intensive use of the land can increase both carbon sequestration and carbon storage capacity. Such 'extensification' of crop or grazing land has been seen in the case of KULUNDA (see the Research insight), where practices that improved biomass above and below ground are also examples to contribute to climate-change mitigation.

There are co-benefits to many mitigation strategies: in the case of rewetting of organic soils and extensification of grasslands, these clearly help to preserve biodiversity and make the whole system more resilient.

Biodiversity conservation

*The Geranium Argus (*Aricia eumedon*). Butterflies can be a sign of diversity. Photograph: Sarah Weking*

Biological diversity does not give a rich and colourful variety of interesting species and ecosystems for the sake only of enjoying life on Earth. Biodiversity is also what characterizes healthily functioning ecosystems – and these ecosystems are nothing less than life-support systems. Without biodiversity, vital 'ecosystem services' (explored more in the next section) are lost, denying humans their numerous crucial benefits, from food and medicines to recreation and renewal.

The variability of biodiverse life is measured within species, between species and across ecosystems. A high level of biodiversity sustains a multiplicity of ecosystem functions and services. The loss of biodiversity that can be caused by anthropogenic global and local change damages ecosystem functioning.

Sustaining life on land and in water form two of the UN's sustainable development goals (numbers 14 and 15) – and SLM means supporting human activities while also preserving biodiversity.

Key insights for biodiversity conservation

Regional research shows that communities and local governments often lack an understanding of the importance and current state of biodiversity. Solutions are difficult to implement if there is no awareness of the problems or benefits of solving them, particularly if the main preoccupations are with production and productivity.

It has long been known that, as agricultural land gets more specialized and intensive, biodiversity gets poorer. Overuse and fragmentation of natural and semi-natural ecosystems and habitats – such as forests, woodlands and steppes – impoverishes biodiversity.

Aside from the new conversion of forests and other natural or largely natural systems in favour of crop production, other drivers against biodiversity include the unsustainable collection of natural products, and excessive grazing. Multiple-pattern, or fine-grained landscape being lost to single-pattern, or coarse-grained landscape – landscape homogenization – also typically induces lower biodiversity.

Recommendations for biodiversity conservation

Strengthen protection of natural and semi-natural systems

Create and protect biodiverse areas by monitoring and reinforcing rules and regulations (see Research insight: LEGATO, a project that developed strategies for diverse habitats, reduced fragmentation, and connectivity ensured by corridors and mosaic landscapes).

Payments and incentives can also be provided as additional benefits for the protection or re-naturalization of land. Yet for land users, biodiverse landscapes have economic benefits that are more difficult to assess and derive compared with farmed landscapes. If ecosystem preservation is a cost to the land's custodians, or if profits from farming are to be affected, compensation or incentives may be needed: payments for ecosystem services, or PES.

Respect the interconnectedness between biodiversity and production

Sustainable intensification and other smart land use needs to protect or improve agrobiodiversity. SLM scientists talk about a 'nexus' of interconnected dependences – and these can be respected by:

- Allowing agrobiodiversity to form an integral part of production systems – examples are conservation agriculture and agroforestry;
- Diversifying within one agricultural system, or among different ones, in a landscape;
- Improving diversity as part of sustaining livelihoods – such as by diversifying production for home consumption or as part of efforts to reduce the risk of production failure;
- Taking advantage of synergistic and by-product effects of practices that are focused on other goals such as climate change adaptation and mitigation (including practices for good soil cover, good soil structure and high biomass production).

Ecosystem services

Ecosystem services are simply the benefits ecosystems provide to human wellbeing. The choice of the word *services* becomes clearer when the direct contribution of water to us is considered, for example. The concept of ecosystems providing us with services was catalysed in the early 2000s when the UN-led Millennium Ecosystem Assessment defined a number of services that ranged, among others, from food, timber, fuel and fibre through air quality and waste processing, to cultural value and amenity. These services may be categorized into three broad groups: provisioning, regulating and cultural ecosystem services. Respective examples are the provision of food, the control of climate or disease, and the recreational benefit of ecosystems.

Key insights for ecosystem services

The assessment of ecosystem services is a complex matter – as is meaningfully communicating findings to scientists, politicians and land users alike.[4] Various decisions about land use lead to differing trade-offs, as one or other ecosystem service responds differently, and as interactions between different services emerge. Potential conflicts can occur between economic interests and ecological, social and cultural values. Less intensive management of a production system can improve biodiversity, for example, but can lead to reduced yield and income. Yet one thing is clear, we cannot choose between preserving ecosystem services or exploiting the land: both are possible – and vital.

While there have been modelling uncertainties in the monetary calculations of this priceless value found in and among the ecosystem services, scientists such as Schmidt et al[5] help in the quantification and transferability of this value of ecosystem services. And where trade-offs for the benefits of conserved ecosystems cannot be balanced locally, PES is the option.

Effective engagement with land users, policymakers and other stakeholders

How can assessments of ecosystem services be delivered in a way that makes enough sense to decision-makers, so that land use and preservation can indeed go hand in hand? One of the outputs of GLUES has been research published in *Ecology and Society*[5] to help answer this question. The key to success in making assessments relevant to decision-makers is simply to focus, at the outset, on the land-use problems they are most concerned with. This means engagement with local stakeholders, building trust, and identifying the economic, cultural and other drivers that have the greatest influence on land-use practices and policies.

In the example of the SuMaRiO project, trade-offs against ecosystem services were caused by cotton production being irrigated with an overreliance on the sole source of water running down from Tian Shan mountains. While the scientific knowledge about the Tarim basin in China was "special", says project lead Prof. Markus Disse, there had been a gap in "putting the pieces together".

SuMaRiO helped with this, to deliver some practical advice to politicians for a five-year plan for the basin, to address sensitive tensions between water distribution, agricultural production, and conservation of forests and biodiversity. The project also developed a detailed decision-support tool based on hydrological models of the basin, enabling people to predict the consequences for ecosystem services of land and water use through clear rating indicators.

Recommendations for ecosystem services

If land is managed sustainably, ecosystems can be flexible enough to meet the changing demands of societies. Sustainable use of ecosystems, including agricultural production systems, can help with mitigating or adapting to climatic, environmental and socioeconomic changes.

4 Förster J, Assessing ecosystem services for informing land-use decisions: a problem-oriented approach, *Ecology and Society*, doi: 10.5751/ES-07804-200331.

5 Schmidt S et al, Uncertainty of monetary valued ecosystem services – value transfer functions for global mapping, *PLoS ONE*, doi: 10.1371/journal.pone.0148524.

Forest above rice terraces guarantees continuous water supply and high biodiversity. The village pictured among the terraces here is Banga'an, in a UNESCO world heritage site in the Philippines. Photograph: Josef Settele

Research insight: LEGATO

Science to enable ecological rice cultivation to compete with intensive methods and provide ecosystem services

The conditions under which ecological rice cultivation can be economically profitable are diverse. In the case of Luzon, the northern island of the Philippines and home to a UNESCO world heritage site, tourism puts pressure on the cost of living. Ecological approaches to pest control in the rice terraces, and not relying on pesticides, are typical for this region. Engagement with farmers who work with this sort of land is worthwhile, helping them to resist the temptation of using pesticides. This takes some persuasion but there are mutual benefits – for the farmers themselves as well as for the broader ecosystem services, says Prof. Josef Settele, who headed the LEGATO project.

The three important strands of ecosystem services in the LEGATO project were provisioning (nutrient cycling and crop production), regulating (biocontrol and pollination) and cultural services (cultural identity and aesthetics). Taking an ecological-engineering approach in these rice agroecosystems – by planting flower strips to benefit pest-regulating arthropods – answers all three by preserving and supporting the biodiversity as well as managing the yields.

The LEGATO project was led by the Helmholtz Centre for Environmental Research – UFZ.

If regional land management considers ecosystem services in the mix, connections and feedbacks are uncovered. Stakeholders are then able to see the 'nexus' between, for instance, biodiversity and resource provisioning. SLM then takes care of all the ecosystem services, not just one trading off at the unsustainable cost of others.

Make assessments of ecosystem services relevant to decision-makers

Taking account of what land users see as the main problems, and targeting decision-makers with context-specific information, helps with policy engagement in the sustainability of ecosystem services.

As was relevant in the recommendations for biodiversity above, PES are an option for policymakers to use when reward for conservation is needed.

Integrate structural landscape elements

Production systems that incorporate riparian forests, flower strips, hedges, earth bunds, terraces and mini-reservoirs all prevent water runoff and soil erosion. As well as improving water availability and quality, benefits include support for integrated pest management and biodiversity (see Research insight: LEGATO).

Improve soil organic matter, carbon content and soil cover

Improving soil organic matter and carbon content improves soil fertility, soil biodiversity, water-holding capacity and carbon sequestration. Maintaining soil cover prevents soil erosion by wind and water, decreases surface evaporation, improves water infiltration and decreases mineralization of soil organic matter, while reducing CO_2 emissions.

Ecosystem services include ecotourism, pictured here in the Philippines. Photograph: Martin Wiemers

Focus on system resilience

Withdraw from any conflict between ecology and economy by orientating production towards stable rather than maximum yields. Such a focus on resilience is especially important against climate change and market fluctuations.

Overall insights

The case for SLM is clear. The practical, scientifically robust research introduced here counters an either/or approach to meeting the growing needs of humankind that would set us against also giving sustenance to wider life on Earth. The need to see ecosystems not as 'them versus us', but as also crucial to human life, is fully realized by sustainable approaches to land management. And this embrace will need to be even firmer as pressures continue to rise with human expansion and climate change. In short, SLM helps to mitigate and adapt to climate change, reduces the risk of disasters, improves management of water resources, contributes to food security and human wellbeing, and is key to the protection of biodiversity. Therefore, not only is the place of SLM firmly established for the decade ahead in the strategy in September 2017 considered by the UNCCD, which makes SDG 15, Life on Land, so important, but SLM must also be seen as critical to other SDGs. Important UN-supported global efforts also include the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES), which investigates the land use–biodiversity nexus. The IPCC also has its imminent special report on the feasibility of the 1.5° C climate target, investigating the impact of climate change on land use and biomass production. In summary, SLM is the key leverage in seven of 17 SDGs.

The research brought together by the GLUES project, and given in overview here, shows how it is possible for land management and specifically agriculture to gain higher, more reliable yields – and yet to do so responsibly. Whether in answer to the themes of food security, water management, climate change, biodiversity or ecosystem services – individually and as an interconnected whole – the seven years of research offer practical solutions to global and local challenges in land use that can be transferred outside of these scientific investigations. Some of the detail given in this policy brief addresses the following:

- On food security, rather than expanding land exploitation, global agricultural yield could be boosted from land already in use, and with sustainability still firmly in place;
- More efficient use of rainwater, plus greater conservation of what is drawn from irrigating sources, can form part of sustainability in practice;
- The management of soil, water and vegetation can be adapted both to help against anthropogenic climate change and to adapt to it – including by reducing greenhouse gas emissions and by helping to remove CO_2 from the atmosphere through land measures;
- The science behind biodiversity and ecosystem services has introduced these concepts as crucial components for sustainable life on Earth, not optional choices. Instead of favouring exploitation of the land over preservation of ecosystems, it is possible instead to do an element of both.

Finally, the overall research programme has found success in ways to overcome the often tricky balance that is needed for the engagement of stakeholders and decision-makers about how best to follow SLM practices – and, crucially, not just how to do so, but *why*. SLM cannot be done without the science, but it is also for policymakers and other stakeholders to make the crucial difference.

Recommended resources

Well-informed land-management decisions

One of the key outputs of the body of research overviewed in this policy brief is a scientific volume of usable technical and practical information. In partnership with the University of Bern Centre for Development and Environment (CDE), UFZ presents *Making sense of research for sustainable land management* (www.ufz.de/makingsense).

Play the policy game

The landYOUs game (http://apps.giscame.com/glues) is an engaging resource for teenagers, but adults too – so why not have a go yourself? Find the right balance for the needs of the land and the population, and get top advice on important indicators from Professor Landstein! By stepping into the role of president, the chaos in Ecotania can be sorted out – and optimal win–wins will attract places on the leader board.

The 12 regional projects of the sustainable land management (SLM) programme around the globe

- LSA 1: Forest systems in the tropics
- LSA 2: Degraded forest/cropland systems in the tropics
- LSA 3: Boreal systems of the western world
- LSA 4: Boreal systems of the eastern world
- LSA 5: High-density urban agglomerations
- LSA 6: Irrigated cropping systems with rice yield gap
- LSA 7: Extensive cropping systems
- LSA 8: Subsistence agriculture
- LSA 9: Irrigated cropping systems
- LSA 10: Intensive cropping systems
- LSA 11: Marginal lands in the developed world
- LSA 12: Barren lands in the developing world

The regional projects from the SLM programme in the context of global land systems. The insights from these will work in other places thanks to the analytical work to reveal land system archetypes (LSAs), which are defined by similarities in land-use intensities and environmental and socioeconomic conditions. Reprinted under licence: Václavík et al, Environmental Research Letters, *doi: 10.1088/1748-9326/11/9/095002.*

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SUSTAINABLE LAND MANAGEMENT
GLUES

HELMHOLTZ
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