UFZ-Discussion Papers

Department of
Ecological Economics and
Environmental Sociology (OEKUS)

4/1999

Supporting Decisions on Conflicting Land-uses: an Integrated Ecological-economic Approach

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August 1999

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Abstract

An integrated ecological-economic decision-making approach is developed to help local stakeholders decide on land use in rural areas where the conflict between natural resource protection and economic development is pressing. It consists of four methodological steps. In the first step the political options and alternatives for action regarding changes in the land-use pattern are specified in order to derive politically relevant land-use strategies (scenarios). In the second step economic, ecological and social indicators are derived. The third step includes economic modelling (economic input-output model), environmental modelling (modelling of landscape water balance) and the qualitative and quantitative estimation of ecological and environmental effects. These efforts result in the production of a multi-indicator matrix. Finally, the fourth step deals with a combined monetary and multi-criteria evaluation resulting in a ranking of the land-use strategies. The discussion of the decision-making approach concentrates on the necessity of preliminary decisions and the possibility and necessity of stakeholders' participation in the decision-making process.

Keywords: *evaluation, decision-making, multi-criteria analysis, land-use management, scenarios, benefit-cost analysis*

1 Introduction

Land use is one of the main factors through which man influences the environment. The pattern of land use is a product of the natural conditions and society's claims on the landscape as a habitat and for economic use. Technical development together with the increasing growth of the human population have increased man's need and ability to shape the environment to his requirements. The very same piece of land may be used in totally different ways and individual land-use types often compete. Land-use decisions are an area of conflict where different societal and private interests clash.

Policy-makers want scenarios to support decision-making (Van de Klundert 1995: 26). Based on scientific evidence, these scenarios are supposed to reflect the economic, social and environmental consequences of decisions which influence land use. This demand has led to various scenario studies and to the development of decision-making tools. Scenario studies are

* The authors gratefully acknowledge critical and helpful comments by Helga Horsch and Bengt Månsson.

used to investigate the consequences of political strategies, for example in the field of the agricultural policy of both the European Union and its Member States (Rabbinge et al. 1994, Baldock et al. 1996). Decision-support systems and tools have been established which are designed to assist the negotiation process between stakeholders (e.g. BELF 1996, O'Callaghan 1996, Schleich et al. 1996, Grabaum and Meyer 1998). In recent years, there has been an increasing number of scenario studies focused on water balance and water quality and their dependence on land use. Although they usually only address environmental interactions (e.g. Mostaghimi et al. 1997, Volk 1999), there are examples of interdisciplinary approaches as well (e.g. Giupponi and Rosato 1999).

On a local to regional scale, many factors which influence land use are beyond the reach of the local stakeholders because they are determined by natural conditions or because they depend on supra-regional developments (e.g. general economic development). Nevertheless, local political action does indeed influence land use. For example, the local administration has certain margins in the implementation of regulations established at superior administrative levels; local Non-Governmental Organisations (NGOs) defend particular interests, e.g. with respect to nature protection; local enterprises seek to strengthen their competitiveness, etc.

Model-based scenario analysis and evaluation require the considerable investment of time and money to set up a comprehensive database (usually GIS-based) and for data manipulation. For the sake of efficiency, it is important to limit the number of scenarios studied and to select the relevant ones early on. This is not a trivial task because compromises must be sought between the requirements of policy-makers (select policy-relevant scenarios) and the feasibility of scientific evaluations (What are the potentials and limits of scientific analysis?). Also, the results of scientific analysis must be evaluated (What developments are desirable/undesirable?).

This paper proposes a framework for the integrated ecological-economic evaluation of land-use management. It is based on a case study in Saxony (Germany) – the Torgau district[1] – where there is a pressing land-use conflict between natural resource protection and economic development. In the area drinking water is extracted for the long-distance water supply company Elbaue–Ostharz GmbH, which can supply about 600,000 m^3 of drinking water daily to a population of 3.5 million. Torgau Waterworks has the capacity to contribute about 40 % to this volume. To protect the groundwater, 33 % of the 686 km^2 of the district of Torgau has

[1] On 1 August 1994 the former district of Torgau merged with the former district of Oschatz to create the district of Torgau–Oschatz. Since most of the well head protection zones are located in the former district of Torgau, our study concentrates on this area.

been declared well head protection zones. In addition, 52 % is identified as landscape and nature protection zones (partly overlapping with well head protection zones). Agriculture, industry, and gravel-mining are bound by certain restrictions within the protection zones. Thus there is a conflict between the protection of natural resources and economic land uses (cf. Horsch and Ring 1999a). The land-use conflicts in the Torgau district are used here to illustrate our decision-making approach. However, the methodology is not restricted to the conflict between groundwater protection and economic development, but also provides a framework to assess a wide range of land-use conflicts in rural areas and to advise stakeholders on deciding on competing land uses. The methodology to deal with this conflict comprises four steps:

Step 1. *Derivation of scenarios*: The pressing conflicts and relevant questions are worked out in dialogue with the local stakeholders.

Step 2. *Derivation of evaluation indicators*: Indicators for the evaluation of alternative political actions are derived from the ideal of sustainable development and discussed with the stakeholders.

Step 3. *Modelling*: The impacts of decisions about changes to current land use are assessed using economic and environmental models.

Step 4. *Evaluation*: The welfare effects of the modelling results are expressed in monetary terms using benefit-cost analysis. Due to the limitations of the benefit-cost analysis the welfare criteria are complemented by non-monetary criteria in a multi-criteria analysis. The results of multi-criteria analysis are finally provided to the stakeholders.

Each of the next four sections describes and explains one of the steps mentioned above. In section 6 the approach is discussed with respect to the influence of preliminary decisions and the necessity of participation.

2 Step 1: Derivation of scenarios

Fields, options and alternatives of action

Political activities influencing land use take place in different *fields of action*. In the Torgau district we investigate two different fields of action: groundwater protection and gravel-mining. Each field corresponds to a political core question. Regarding groundwater protection it runs: “What extent of protection and utilisation is reasonable taking into account ecological interactions and the economic demand for water? What size of well head protection zones is necessary to secure the drinking water supply in the long run?" And regarding gravel-mining: "In view of the expected development of the demand for gravel and the ecological impacts of gravel exploitation for the time horizon considered (until 2030), is it reasonable and necessary to grant further licences for gravel-mining in the Elbe river plain during this time span?"

For each field of action there are several *options* in the public debate over how to decide and to act. The main options of action in the political discussion are (Geyler 1999, Messner 1999)

1. Concerning groundwater protection:
   a) No reduction of the well head protection zones
   b) Slight reduction of the well head protection zones
   c) Large reduction of the well head protection zones
2. Concerning gravel-mining:
   a) No licences for additional gravel mines
   b) Granting licences for additional gravel mines

In each field of action an option can be chosen independently of the choice of options in other fields, even though the choice of a certain action generally has impacts on the other action fields. For instance, the reduction of a well head protection zone implies consequences for the exploitation of gravel, since mining is restricted within these areas. Therefore, it makes sense not to consider each field and option of action independently, but to explicitly take the interdependencies between the options into account. In principle, all the logical combinations of the options of the different fields of action must be mutually compared. We call such a combination of options an *alternative action* or simply *alternative*. The Torgau political actors have two fields of action with three and two options, respectively. Hence, they can choose between six different alternative actions (cf. Tab. 1):

Tab. 1: Alternative actions of the political actors in the Torgau district.

		Fields of actions	
		Well head protection zones	Gravel-mining
Alternative actions	1	No reduction	No additional licences
	2	No reduction	Additional licences
	3	Slight reduction	No additional licences
	4	Slight reduction	Additional licences
	5	Large reduction	No additional licences
	6	Large reduction	Additional licences

Parameters, framework of development and scenarios

In order to be able to responsibly evaluate alternative actions, the resulting developments have to be simulated. This is done either by models or qualitative and quantitative impact assessments (cf. Sec. 4). However, the future developments also depend on factors which cannot be influenced by the decision-makers. Such factors are called *parameters*. Mutually exclusive, distinct constellations of parameters are denoted as the *developmental framework*.[2]

Within the Torgau project, important parameters include economic growth, the consumption of drinking water, gravel production per unit of gross domestic product (GDP), and the demographic development, etc. For simplicity's sake, we only distinguish between two developmental frameworks – an optimistic and a pessimistic one. The optimistic framework assumes a relatively high average rate of economic growth (4.4 %), as well as a constant demand for drinking water and an increasing demand for gravel. The pessimistic framework is characterised by low average economic growth (2.5 %) and declining demand for gravel and drinking water (cf. Klauer et al. 1999, Geyler 1999, Messner 1999).

The actual impacts of alternatives depend on the respective developmental framework. If all alternative actions are to be compared, all combinations of alternatives and developmental frames must be considered. A combination of one alternative and one framework is termed a *scenario*.[3] In our case, for each alternative action, two different scenarios are obtained. Since it has to be decided between six different alternatives, we therefore have to investigate twelve scenarios (cf. Fig. 1).

3 Step 2: Derivation of evaluation indicators

We assume that the stakeholders in the Torgau region use several *indicators* to structure the assessment of the consequences of decisions. Sustainable development (cf. WCED 1987, BUND and MISEREOR 1996: Chap. 4, Bühler-Natour and Herzog 1999, Klauer 1999a) has been widely used in recent years as an ideal for environmental policy on both the global and the regional scale (Agenda 21 and Local Agenda 21, cf. UNCED 1992). For this reason we suppose that the decisions are made based on the ideal of sustainable development.

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[2] In the literature of decision theory mutually exclusive constellations of parameters are frequently called "state of the world". We believe this static notion to be unsuitable in our context.

[3] Our definition is consistent with that of Veeneklaas and van den Berg (1995: p. 11), which states: "a scenario is a description of the current situation, of a possible or desirable future state as well as of the series of events that could lead from the current state of affairs to this future state."

Consequently, indicators must be chosen which on the one hand reflect the interests of the local decision-makers and, on the other hand, include the major and specific economic, ecological and social aspects of the ideal of sustainable development for the region and the problem under consideration.[4] For the Torgau district, to reflect the major economic impacts of the scenarios, the indicators chosen are aggregated welfare effects and value added. Regarding the social aspects, the indicator employment was selected, because the high rate of unemployment is the largest social problem in the Torgau district. In respect of environmental and ecological effects, the chosen indicators are groundwater balance, the nitrogen load of the groundwater and development of biodiversity. If the scenarios are put into the rows of a matrix and the indicators in the columns, the resulting table is called a *multi-indicator matrix* (cf. Fig.1).

4 Step 3: Modelling

The impacts of an alternative have to be simulated by models which yield values for the indicators selected in Step 2. The impacts of decisions about land-use changes are assessed using economic and environmental models.

In the Torgau case study a water balance model and an economic input-output model are applied. The water balance model computes long-term average values of groundwater recharge (Glugla and Fürtig 1997, Petry et al. 1999). Farm surveys are conducted to compute nitrate balances (Hülsbergen 1997) for selected fields according to different levels of production intensity (conventional – integrated – organic), of protection zones (well head protection zones, unprotected) and of natural conditions (the loamy riverplain area along the Elbe river, adjacent sandy areas). The nitrate concentration in the percolation water can be estimated from the percolation water level and nitrogen surpluses (Wendland and Bach 1994). The results are extrapolated spatially using a geographic information system.

The modelling of the economic impacts of changes to land use are based on input-output analysis (cf. e.g. Miller and Blair 1985). The dynamic model (Klauer 1999) describes the monetary and the material interlinkages between the different sectors and the capital accumulation in the regional economy. Hence it is possible to gauge both the direct and the indirect effects of land-use changes. The impacts on total production, the value added and the

[4] For more on the discussion about indicators for sustainable development within the OECD and the Commission for Sustainable Development (CSD), cf.: SRU (1998, Chap.1.4).

number of employees are calculated for each scenario. Moreover, the model can be used to simulate the economic use of environmental goods and services (e.g. the consumption of drinking water or nitrate emissions) related to the scenarios.

The derivation of the scenarios and the choice of the indicators form the basis for modelling. The results of modelling yield a multi-indicator matrix which assigns a value to each indicator for all scenarios (cf. Tab. 2).

Tab. 1 Multi-indicator matrix.

Multi-indicator matrix			Indicators			
			a	b	...	m
Alternative actions / scenarios	1	Pessimistic	a(1,Pess.)	b(1,Pess.)	...	m(1,Pess.)
		Optimistic	a(1,Optim.)	b(1,Optim.)	...	m(1,Optim.)
	2	Pessimistic	a(2,Pess.)	b(2,Pess.)	...	m(2,Pess.)
		Optimistic	a(2,Optim.)	b(2,Optim.)	...	m(2,Optim.)
	⋮		⋮	⋮	⋱	⋮
	6	Pessimistic	a(6,Pess.)	b(6,Pess.)	...	m(6,Pess.)
		Optimistic	a(6,Optim.)	b(6,Optim.)	...	m(6,Optim.)

5 Step 4: Evaluation

One special feature of our evaluation approach is the combination of monetary and non-monetary evaluation criteria in the same evaluation scheme. Thus, the values of the criterion “net benefit” as the result of benefit-cost analysis is integrated into a multi-criteria framework as *one* criterion among other, non-monetary ones. In the following, the methodological basis of this approach is described.

Monetary evaluation

The rationale of monetary evaluation is to express the welfare effects of a project or a scenario vis-à-vis a reference state of the world in one generally accepted unit: money. The method used is called benefit-cost analysis and the result is the monetary net benefit of the scenario considered compared to the reference scenario. Usually, the methodological procedure of a benefit-cost analysis comprises eight stages (cf. Hanley and Spash 1993, pp. 8-19). Stage one consists of scenario definition and is identical to step one of the integrated evaluation approach presented in this paper. Stages two and three include the identification of actual effects and the choice of the relevant effects that are to be ultimately evaluated. These stages correspond to the derivation of evaluation indicators in step two of our approach. Stage four comprises the quantification of the relevant effects in physical units. Here, the economist carrying out the benefit-cost analysis quantifies the economic effects, while for most of the effects in the natural environment he relies on external scientific experts. This stage four relates to the modelling step in our evaluation procedure. Stages five and six of a benefit-cost analysis refer to the actual monetary evaluation of the quantified real effects as well as to the discounting of future values in order to express them in present values. Finally, in stages seven and eight the net benefit of the scenario considered is calculated in present value terms and the impact of important parameters is tested in a sensitivity analysis. The methodological procedures of stages five to eight are the subject-matter of step four in our evaluation approach as far as the monetary part of the evaluation is concerned.

In order to produce comparable results in the monetary evaluation of different scenarios, one scenario must be chosen to function as the reference scenario for a given developmental framework. If the net benefit of all other scenarios is calculated against the chosen reference scenario, the consequent results bring about comparable monetary values.

This is not the place for a detailed discussion of all the elements of a benefit-cost analysis. However, to clarify the methodological concept, some examples are given of how effects in the real world can be expressed in monetary terms. The setting for the examples is the conflicting situation between drinking water protection and gravel-mining in the district of Torgau. Scenarios 5 and 6 as described in section 2 are considered. Scenario 6 serves as the reference scenario with large reductions in the well head protection zones with additional licences granted for gravel-mining. Scenario 5 relates to the case that no additional gravel-mining licences are granted despite large reductions in the well head protection zones. Thus, the question to be answered by the analysis reads: “What positive or negative welfare effects will arise if the production capacity of gravel-mining is not increased for the time under consideration?”

The most important **costs** of not granting further gravel-mining licences are: there will be no increase in profits for the gravel-mining industry; no further employment will be created directly or indirectly; and there will be no gravel-mining pond for recreational activities due to the flooding of the pit after the end of the mining activities. These costs are called opportunity costs of not extending the gravel-mining capacity. The opportunity costs relating to the mining industry are the foregone mining profits that can be estimated in monetary terms based upon economic forecasts regarding future trends in the gravel market (future development of gravel prices, development of future demand, development of industry cost structure). The opportunity cost of not having a gravel-mining pond in the future for recreational use can be approximated by the costs of run a public swimming bath with a similar capacity minus the costs of guarding and cleaning the mining pond beach in the future.

The major **benefits** of not extending the gravel-mining capacity are: no increased costs will be incurred by the waterworks to ensure the water supply in the long run; there will be no additional lorry transports causing higher levels of pollution and noise, a faster deterioration of roads; and the potential gravel pit location near the River Elbe can be preserved for agricultural use and as a location for nature protection where a floodplain area can be restored. Most of these benefits can be expressed in monetary terms. The avoided additional costs of the waterworks to clean the water and/or to supply water from other parts of the region can be counted as benefits. Regarding the prevented transport emissions, their benefits can be approximated by the marginal costs of reducing the expected amount of prevented emissions at other pollution sources in the region. The opportunity benefits of preventing a higher level of transport noise can be estimated by the costs of necessary additional noise abatement measures that would have become necessary in the case of increased mining capacity. Furthermore, there are benefits in the form of the avoided higher public costs of repairing the highly frequented roads in the region. Finally, the preservation of fertile arable land means that more agricultural profits can be realised compared to the case of increased mining.

Despite the fact that many welfare effects can be expressed in monetary terms through the use and extrapolation of present market prices, there are still several effects that are not adequately considered in the methodological framework of a benefit-cost analysis. On the one hand, there are some *economic* problems. Since full employment is a basic assumption of benefit-cost analysis, unemployment is not considered a social cost; on the contrary, the use of less labour is treated as a benefit, because it implies higher productivity and lower production costs. As a consequence, the higher level of employment that could be achieved by increasing the gravel-mining capacity is not reflected in the benefit-cost calculations. Furthermore, the aggregation of net benefits indicates that the losses of one affected group can be compensated by equal gains to other persons. However, the marginal utility of money changes with the amount of money earned or owned. Thus, benefit-cost analysis does not reflect changes in the distribution of wealth within an economy. On the other hand, it is almost impossible to place a value on irreversible effects like the loss of a species or a rare kind of ecosystem (Funtowicz and Ravetz 1994). Even though there is much in the literature on the application of direct valuation methods ("contingent valuation"), which ask people how much money they would be willing to contribute to measures that could prevent species or ecosystem losses in order to identify respective shadow prices (cf. among others Loomis and Gonzalez-Caban 1998 as well as Hanley 1988), these direct methods are characterised by some fundamental flaws. Firstly, the interviewees are only confronted with a hypothetical situation and do not actually have to pay anything; secondly, the information about the subject is often incomplete and cannot be complete due to future realisation about the subject under consideration (e.g. a lost species might have become the key to cure AIDS or cancer); and thirdly, the preferences of future generations cannot be included in monetary valuation (cf. Daly and Cobb 1989: 141-143, Klauer 1998, Messner 1999: 166, Geyler 1999: 136-140). To sum up, it must be stated that the benefit-cost analysis is unable to reflect essential economic, social and ecological aspects which are crucial in evaluation if the ideal of sustainable development is acknowledged as a basic goal.

Due to these and other methodological weaknesses of monetary evaluation, the benefit-cost analysis is integrated in a multi-criteria approach that combines criteria derived on the basis of the general economic, social and environmental goals related to the concept of sustainable development. However, the consideration of monetary values remains important, because every political decision in the real world takes monetary values directly or indirectly into account. Therefore, as many social and environmental effects as possible are expressed in monetary terms in order to include them in the calculations. Yet at the same time, it has to be recognised that money is not a universal measure.

5.2 Multi-criteria evaluation

Adequate evaluation criteria must be derived to complement the welfare criteria of the benefit-cost analysis. They must compensate for the weaknesses of benefit-cost analysis described above. The starting-point is the sustainability indicators as defined in Step 2. Since indicators measure pure quantities, for instance the extent of the nitrogen load in groundwater, but do not include information about which loads are harmless or dangerous, evaluation categories have to be developed that take present legislation and scientific knowledge into account and that also reflect the spatial distribution of effects. Such categories that allow for a ranking of values are called *evaluation criteria*. The modelled indicator values are to be assigned to these evaluation schemes.[5] As a result, the multi-indicator matrix is transformed into a multi-criteria matrix that finally constitutes the foundation for applying multi-criteria analysis.

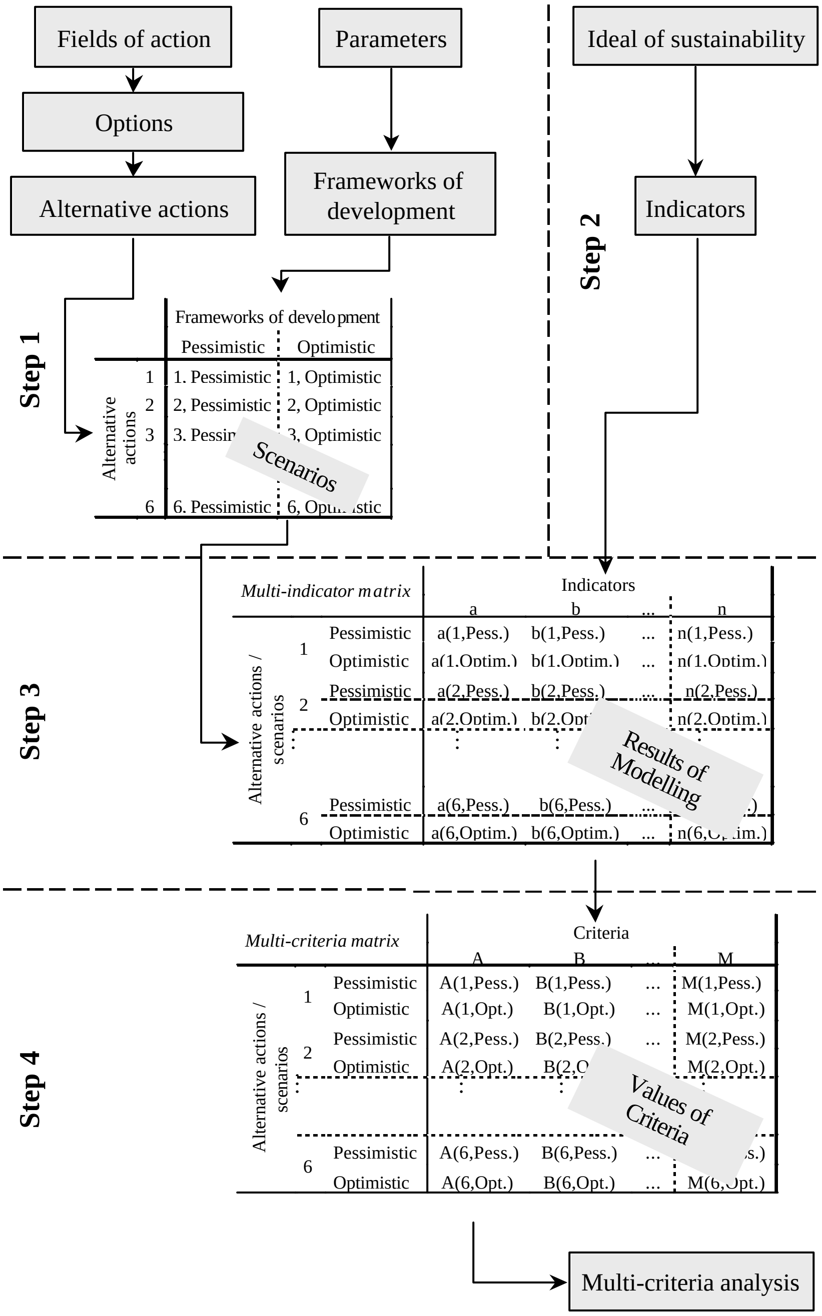

Figure 1: The four steps of the integrated decision-making approach

[5] This does not mean that every indicator is transformed into a single criterion. At times it might be necessary to define a criterion based upon different indicators, while sometimes several criteria might need to be identified in order to reflect one indicator. Therefore, the number of indicators (n) need not equal the number of criteria (M) in Figure 1.

An important distinction in multi-criteria analysis is between multi-criteria decision-*making* and multi-criteria decision *aid* (Roy 1990). Multi-criteria decision-making means selecting an action in a well-stated decision context with multiple criteria. By contrast, multi-criteria decision *aid* does not recommend an optimal decision in a certain sense; instead, it helps the decision-maker to either select or group the possible actions and to make clear to him the consequences of his decision.

In our case study we offer both multi-criteria decision-making and aid to the decision-makers. Our method for multi-criteria decision *aid* graphically groups the alternatives such that the trade-offs and complementarites between the different criteria and respective aims become apparent (Drechsler 1999).

Our algorithm for multi-criteria decision-making (Drechsler 1999) is based upon the PROMETHEE procedure (cf. e.g. Munda 1995), which is adjusted to allow for uncertain situations regarding the exactness of criteria values. As a result, a priority ranking of the scenarios can be presented. If the scenarios are examined for different developmental frames, there are as many ranking results as frames considered.

Principally, multi-criteria decision-making demands weighting the evaluation criteria. This weighting cannot be performed by scientists alone. Instead, similar to the process of scenario derivation, the local decision-makers must be involved in order to find one or several weighting solutions. Finally, with data reflecting the net benefit from the benefit-cost analysis, with the modelled indicator values set in relation with the sustainability criteria, and with a weighting system at hand, the multi-criteria algorithm can be applied.

Thus, by applying multi-criteria analysis the decision-makers can be provided with a wide range of information concerning the optimality of land-use alternatives for different developmental frames. Ultimately, it is their task to decide. In Figure 1 the four steps of the integrated evaluation procedure that might be used as an integrated decision-making approach are presented graphically.

6 Discussion

In this paper, an integrated evaluation approach has been presented that can be applied to support the decision-making process with regard to the choice among different land-use management strategies. The approach provides a framework to assess land-use conflicts in rural areas and to advise stakeholders on deciding on competing land uses. We have used the land-use conflicts in the Torgau district to illustrate our decision-making approach. However, this approach is not restricted to the conflict between groundwater protection and economic development. Compared to other evaluation approaches, the approach presented has three distinguishing features.

Firstly, it is a holistic approach. It considers the evaluation process from the very beginning (analysis of land-use conflicts, derivation of scenarios) up to the stage when the decision is to be made. Furthermore, it includes the scientific disciplines needed to produce an adequate basis of information. The functioning of interdisciplinary co-operation is essential in order to include those problems and conflicts that can only be analysed properly if interdisciplinary interdependencies are considered.

Secondly, in contrast to evaluation approaches that only rely on monetary or environmental approaches to assess different kinds of land use, the approach presented here integrates both methods in a manner including the advantages of both evaluation procedures. With welfare effects expressed in monetary terms, politicians acquire an understanding of the economic impacts of their land-use decisions, while features not included are presented in the form of additional ecological, social and economic criteria. Along these lines, all kinds of important information can be presented.

Finally, the approach presented is open to the participation of stakeholders in all phases – although this participation is certainly most extensive in final phase. The decision-makers use the information from the multi-criteria analysis with respect to the optimality of land-use alternatives for different developmental frameworks in order to actually decide.

However, participation is necessary at earlier stages, too, since many *preliminary decisions* that may involve imperative evaluations are necessary at all steps of the evaluation approach presented. For example, in order to derive the alternative actions, scenarios and evaluation criteria, vital preliminary decisions that always have to be made, explicitly or implicitly, are:[6]

- What fields and options of action are to be considered?
- What parameters are relevant?
- What indicators reflect the essential aspect of the ideal of sustainable development?
- On which evaluation measures are the criteria based?

[6] Principally, it is possible to apply a separate decision-making tool for each preliminary decisions. However, these decision-making methods in turn need preliminary decisions. To escape from such an infinite regress, which would increase the decision costs infinitely, the preliminary character of decisions based on scenarios and criteria must be accepted.

The fact that every decision-making method is influenced by more or less intuitively made preliminary decisions becomes particularly relevant, if – as is the case in the Torgau project – the scenarios and criteria are not derived by the persons who actually hold the power of decision. The preliminary decisions need to match the intentions of the decision-makers such that the results of the decision-making approach are accepted and adopted by the decision-makers. Acceptance can be considerably improved if the decision-makers participate in the phases of scenario and criteria derivation. Only if the preliminary decisions match the decision-makers' intentions will the scientific accompaniment of the decision-making process help the solution desired by society to be found.[7]

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[7] Van Walsum et al. (1995) describe a project where extensive preliminary decisions are made by the accompanying researchers. In the project, a method for deriving an optimal decision was developed. The sole possible influence of the politician was to assign weights to different evaluation criteria. Applying their decision-making method in practice, the authors were surprised that the politician did not accept their restricted role. In the light of our discussion, the reaction of the person actually holding the power of decision would have been foreseeable.

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