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Scenario Methodology for Modelling of Future Landscape Developments as Basis for Assessing Ecosystem Services

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Abstract

The ecosystems of our intensively used European landscapes produce a variety of natural goods and services for the benefit of humankind, and secure the basics and quality of life. Because these ecosystems are still undergoing fundamental changes, the interest of the society is to know more about future developments and their ecological impacts. To describe and analyze these changes, scenarios can be developed and an assessment of the ecological changes can be carried out subsequently. In the project „Landscape Saxony 2050"; a methodology for the construction of exploratory scenarios was worked out. The presented methodology provides a possibility to identify the driving forces (socio-cultural, economic and ecological conditions) of the landscape development. It allows to indicate possible future paths which lead to a change of structures and processes in the landscape and can influence the capability to provide ecosystem services. One essential component of the applied technique is that an approach for the assessment of the effects of the landscape changes on ecosystem services is integrated into the developed scenario methodology. Another is, that the methodology is strong designed as participatory, i.e. stakeholders are integrated actively. The method is a seven phase model which provides the option for the integration of the stakeholders' participation at all levels of scenario development. The scenario framework was applied to the district of Görlitz, an area of 2100 sq km located at the eastern border of Germany. The region is affected by strong demographic as well as economic changes. The core issue focused on the examination of landscape change in terms of biodiversity. Together with stakeholders, a trend scenario and two alternative scenarios were developed. The changes of the landscape structure are represented in story lines, maps and tables.

On basis of the driving forces of the issue areas „cultural / social values" and „political control", three scenarios were developed up to the time horizons in 2030 and 2050. They are titled „Trend", „Tradition and Ecology" and „Technology and Energy". These scenarios differ markedly in the degree of the future lignite exploitation, in the use of renewable energy and in the environmental compatibility of the agricultural production.

In total, the investigation shows that the integration of the ecosystem services approach into the scenario technology has brought new aspects. However, the procedure became more complex.

For the development of the scenarios a precise definition of the driving forces turned out to be essential. The experiences of the project further show that only two or at most three key driving forces (KDF) can be distinguished really sensibly or can be looked at in their interactions.

It could be shown that from these results itself concrete measures can be derived which support desirable developments or counteract against undesirable effects. By the integration of stakeholders in different working steps, the scenarios can contribute to the sensitization and better perception of future problems and chances of a region.

Keywords:

actors, landscape change, participation, future research, scenarios, drivers, ecosystem services

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1 Introduction

1.1 Motivation

Ecosystems provide a large number of services for the benefit of humankind (Costanza & Daly 1992, De Groot et al. 2002, Liu et al. 2009). Such "ecosystem services" (ESS) secure our foundations of life and ensure its quality, e.g. by providing food, the basis for tourism and culture, or protection against soil erosion (MA 2005). However our landscapes are being transformed ever more rapidly (Antrop 2005, Haase et al. 2007). The reasons for this include increased use of renewable energy sources, increased intensification of agriculture, demographic changes, and the still unhampered expansion of areas used for residential and transport purposes. On the base of several scenarios, it is possible to identify what these developments will be like for certain ecosystem services, and how humankind can intervene in a directive manner (TEEB 2009, Carpenter et al. 2006).

The drafting of scenarios is one of a number of possible approaches to investigating future developments; other methods for future research include e.g. Delphi studies (Dörr 2005), prognoses (Jessel 2000), trend projections (Bork & Müller 2002), role playing (Armstrong 2002), neuronal networks (Pijanowski et al. 2002), the analysis of binding planning documents and policy goal statements, and landscape experiments (Oppermann 2008). The scenario technique could function as a bridge concept for interdisciplinary work in research of the human-environment relationship (Santelmann et al. 2004).

The scenario technique is considered an approach to addressing the question of sustainability (Walz et al. 2007), since the assessment of intergenerational justice requires a plausible view into the future, involving, among other things, an investigation of long-term developments.

Scenarios are defined as "plausible and often simplified descriptions of how the future will develop, based on a coherent and plausible set of assumptions on key driving forces (KDFs) and relationships" (MA 2005). Alcamo (2008) states: "A scenario is a description of what the future will look like on the basis of if-then statements, and is typically based on a representation of the initial situation and the description of key driving forces and changes, which will lead toward a certain future condition." Or, to put it more simply: "Scenarios are hypothetical results of events which are designed to highlight the consequences of certain decisions" (Rotmans et al. 2000).

There are two basic forms of methodological approaches to the scenario formulation: first, scenarios may be developed as a kind of narrative storyline, an option which we have preferred here. Second, there are quantitative approaches under which model-based simulations are used. Another manner of distinction is a breakdown by normative scenarios, in which desired versions of the future are depicted and contrasted to projected scenarios describing causal projections caused by driving forces (Nassauer & Corry 2004); see Figure 1. Geoinformation systems (GIS) are often used for the modelling of landscape changes (Steinitz 2003, Zebisch 2004).

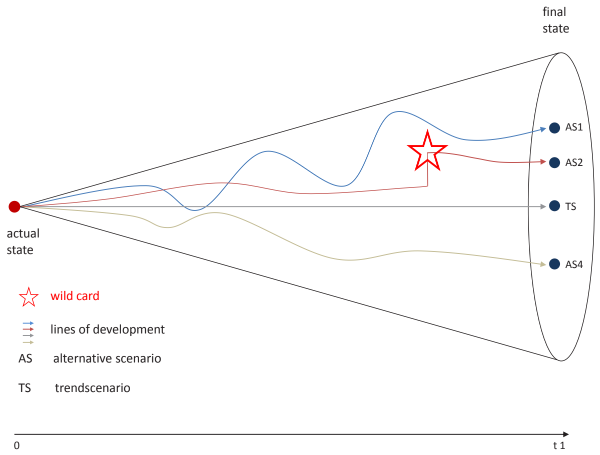

Figure 1: Depiction of a scenario cone
Own Design

However, the distinction is also made between participatory and expert scenarios, with the latter usually structured quantitatively, and the former, qualitatively (Rotmans et al. 2000).

There is a trend toward combined scenario methods (Walz et al. 2007), which both contain qualitative/participatory elements, and are underpinned by quantitative models. The difficulty is the combination of these two techniques, because the results of participatory processes cannot be directly integrated into quantitative models, and mathematically abstract modeling results are often not understood by actors.

The scenario technique familiar today has been developed in the context of future research and as a method for a prognosis of the effects of nonlinear processes (Kahn & Wiener 1984). The scenario technique achieved great public attention as a result of the study 'The Limits of Growth' by the Club of Rome (Meadows et al. 1972). A scenario technique designed to meet the above stated demands would have to combine methodological elements from environmental research and from corporate planning, but would also have to adapt them to the particular needs of landscape development. As a basis for our methodology, we have in particular used the work of Reibnitz (1991) and of Gausemeier et al. (1996, 2009) in the area of business administration, and also of Alcamo (2008) in the area of environmental science.

The greatest challenge to date facing the further development of scenario methodology has been that of visual preparation and conveyance in a manner appropriate to the recipients of the multifaceted scenario results, which are usually difficult to comprehend. The core paradigm is the basic methodological structure of Integrated Assessment (IA), which has been used in the Visions Project (Rotmans et al. 2000) and elsewhere. Examples of integrated human-environment research projects with the aid of scenarios include the Millennium Ecosystem Assessments (MA 2005), and the Global Environment Outlooks of the UNEP, the fourth generation of which is now available (UNEP 2007); the fifth generation is currently under discussion (UNEP 2011).

At the same time, a growing number of publications are addressing environmental scenarios and their evaluation by means of landscape functions, or through the concept of ecosystem services. These include Fidalgo & Pinto (2005), Nassauer et al. (2002), Dunlop et al. (2002) and Seppelt & Holzkämper (2007). The Fourth Assessment Report (Pachauri & Reisinger 2008) of the Intergovernmental Panel on Climate Change (IPCC) is an investigation which addresses the effects of climate and socio-economic change at the global level, and examines a wide range of ecosystem services. At national level, the project Natural Capital Germany – TEEB DE (2013) deals with changing ecosystem services as well as the development of possible action options.

1.2 Goals of the study

The project upon which this study is based, Landscape Saxony 2050, is oriented towards an investigation area of medium size. In addition to the practical testing with a total of three different scenario runs, the major goal was the development of a consistent and easily applicable methodology, which would particularly take into account the participation of a broad segment of the public and of decision-makers. For this reason, this methodology of scenario development is presented in Chapter 2 in the form of a manual-like set of directions, and the results are only touched on briefly in Chapter 3. In this form, the methodology has the purpose of establishing exploratory scenarios which are to enable the effects of future landscape changes to be assessed on the basis of the Ecosystem Services approach.

The Ecosystem Services (ESS) approach and the combined landscape scenarios should be integrated to the extent that as little additional effort as possible is generated, and the overall methodology remains manageable and comprehensible to the participants. Even in the first work steps of scenario development, the ESS approach should be used in order to filter out the interesting issues, to identify relevant drivers, and to describe the initial situation of the scenarios. During the course of scenario development, the statements on the future are spatialized by GIS in the form of a cartographic foundation for later ESS-referenced evaluation.

The purpose of the step-by-step construction of the scenarios is to make that process an interactive form between the relevant interest groups. These interactions provide the possibility to sharpen the perception for regionally specific future-relevant tasks and issues.

The area under investigation is the district of Görlitz, an area of approx. 2100 sq km characterized by significant population shrinkage and insecure economic perspectives. It is facing major challenges, but also has considerable potentials in the form of its cultural peculiarities and its natural treasures – raw materials, protected areas, large un-fragmented spaces, historic parks, and touristic attractions. These potentials provide possibilities for developments which can be displayed in storylines, maps and tables. On this basis, measures should be discussed and balanced, in order to promote desirable developments and to counter undesirable effects.

2 Methodology

In the scenario technique presented here, the explorative forecast approach is used (Alcamo 2008), a relatively open-ended approach. That means that, in contrast to the formulation of normative scenarios with concrete goal definitions, the range of acceptable developments is not limited. A combined use of quantitative and qualitative procedures is possible.

The methodology developed by the authors consists of seven work phases, which however do not all need to be run through in each case of application or specification. Figure 2 gives an overview of the step-by-step structure of the procedure.

Phases 1 through 6 are run through sequentially, since the results of each phase are needed for the following one. Phase 7 includes first of all the transfer of scenarios, which largely takes place at the end. Secondly, throughout the entire scenario development, the use of various participation methods for the inclusion of a broad segment of the public is provided (Phases 1-7). Based on the assessment and the discussion of the results in Phase 6, a revision or the drafting of further scenarios may become necessary as indicated by the back loop arrow.

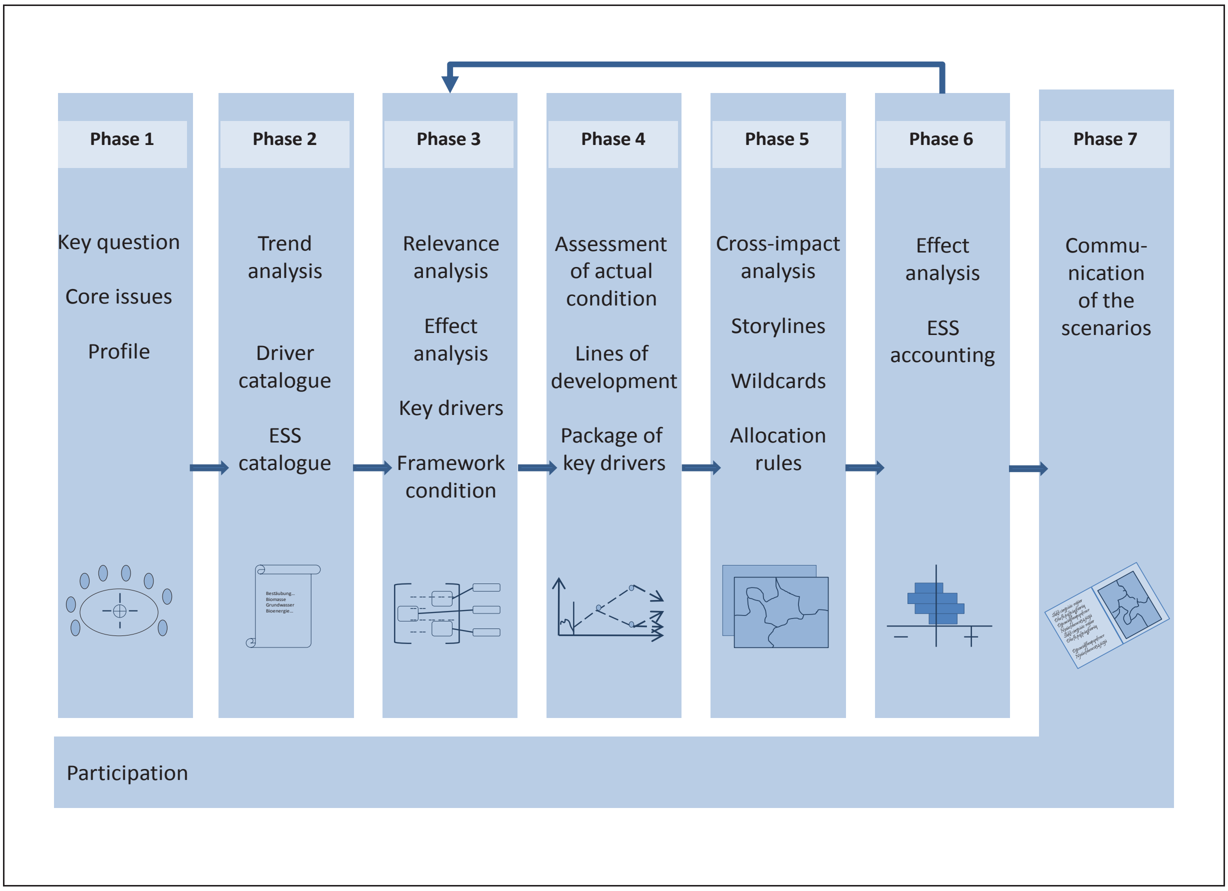

Figure 2: Work phases of scenario development
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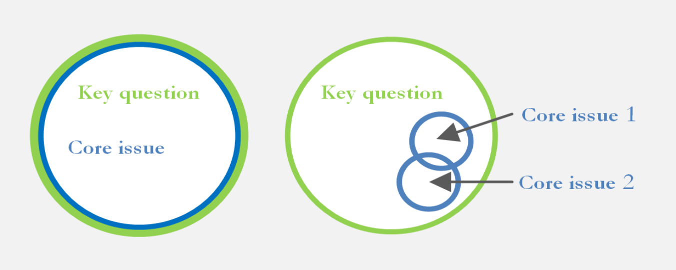

Figure 3: Phase 1 of scenario development
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2.1 Phase 1

In Phase 1, the scenario process is prepared organizationally, and the object of the investigation is defined through the formulation of the key question by the scenario team, which controls scenario development, and which can consist of experts and/or various actors; if necessary the object of the investigation can be specified more precisely by means of special core issues. The key question determines the overarching goal definition. That includes the essential ancillary conditions, such as the timeframe of the scenarios, and the limitation of the area to be investigated. Once the key question has been defined precisely enough, this phase is completed. However, if the range of issues defined is very extensive, the object of the investigation could be defined more precisely by means of the determination of core issues; see Figure 3. Each core issue thus focuses on one area within the range of problems formulated by the key question. It is useful to record all important information for each core issue in a separate scenario profile, which is established step-by-step in the following work phases. In this phase, the possibilities for participation in the following phases by various actors or by the public are organized and established.

2.2 Phase 2

Phase 2 includes the establishment of those effect factors which are taken into account as the drivers of landscape development in the scenarios, as well as the selection of the ESSs to be processed. It is thus important to determine which factors are significant for establishing the key question and the core issue, and which especially have an effect on the services to be examined. The selection of those services must therefore also be carried out during this stage of work, since ESSs and drivers are mutually conditional. For the ESSs, there are catalogues such as TEEB (2009) or Carpenter et al. (2006), which can facilitate the selection. However, the exact definition and the appropriate selection of effect factors or “drivers” are decisive for the success of the entire project. An exact analysis permits the identification of more than 100 different effect factors, so that the compilation and selection can be very time-consuming. The important thing is that at the end of this work stage, a limited number of drivers – if possible, not more than ten – remain (cf. Syrbe et al. 2013), and that each one of them be clearly defined as a measurable indicator with reference and measurement units, sources and current actual values. For the selection of effect factors, the literature provides a large number of methodological variants, including not only brainstorming, expert discussions and criteria-based ranking, but also effect and preference analyses with the aid of matrices.

The substantive foundation is formed by analyses of the situation or of trends, the results of which are established in the profile. The usual methods for that purpose include spatial analyses of changes to date on the basis of land-use data (CORINE, ATKIS, biotope mapping, long-distance investigative data, historical maps, or statistical data), leading to transfer matrices. Qualitative methods used include reviews of the literature, surveys, and interviews with experts, which may be supplemented for issues relevant for the landscape or for planning by the evaluation of planning documents. The essential result is a specific driver catalogue referenced to the core issue, with initial trend statements.

2.3 Phase 3

In Phase 3, it is necessary to determine which of the drivers ascertained are applicable for all future drafts, and which flow into the scenario in a differentiated manner. The purpose of a scenario development is to investigate various – possibly opposite – developments by assuming different processes for one or more of these drivers. However, such a distinction is only meaningfully feasible for very few drivers. For all other factors, a very definite, uniform development is assumed, characterized as exactly as possible (preferably quantitatively as well), and thus established for all later scenarios. Optimally, prognoses will already be available for these factors, or projections can be calculated by means of trend extrapolation. We call these uniform established quanta “fixed effect factors” or “framework conditions”. By establishing framework conditions, the leeway for different possible developments will be greatly reduced, and the development of further scenarios considerably facilitated.

The variable drivers, on the other hand, broaden the scope of possibilities of various future outcomes, and are therefore identified as “key drivers”. Determining them is one of the most important milestones in scenario development, and should accordingly be coordinated well with all participants. Since the selection of a large quantity is difficult, the approach should be the other way around: one important key driver should be negotiated, and then supplemented by a second one, and, if absolutely necessary, by a third one. Central to the selection process in terms of substance should be “control instruments”, with the aid of which the development can in fact be influenced in order to be able to arrive at substantively significant policy conclusions. The key drivers selected will be described in greater detail. For this purpose, additional research will be necessary, and external experts could be involved.

2.4 Phase 4

In Phase 4, the important issue is to undertake an exact characterization of the initial condition. All selected ESSs are evaluated, for which purpose the EPPS concept (Bastian et al. 2011), which is integrated into the methodology, is particularly well suited. The important thing is to show which service potential a landscape has, and can render sustainably. On this basis, assumptions on future developments of key drivers can be drafted, and their so-called “progression types” defined. The classification shown in Figure 4 is suitable for a schematic description.

For these progression types, decisions must be made as to whether the extrapolation of current trends can be assumed as one of a number of developments for all or for some drivers; unlike for

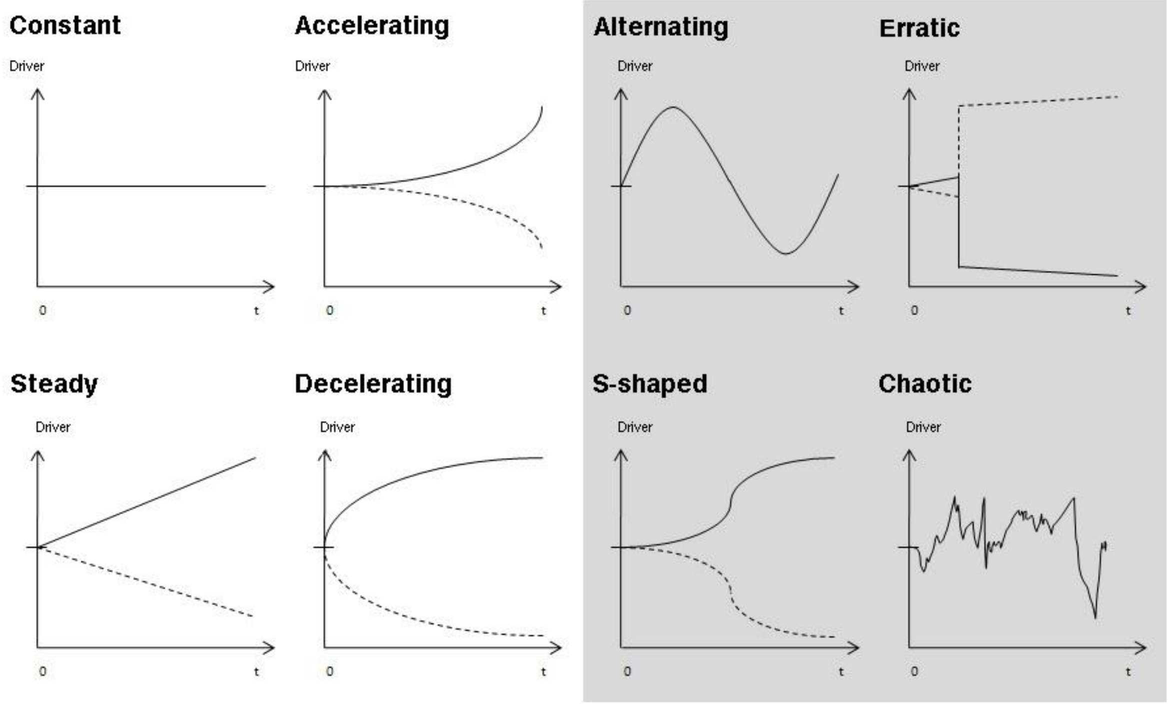


Figure 4: Basic progression types (left) and possible combinations for the key drivers of scenario development
Own Design

the fixed factors, however, non-linear progressions can also be assumed, i.e., if a trend weakens, reverses, or alternates. If the progression types for certain drivers are entered into overview tables as pictograms (Figure 4), it becomes relatively easy to show how changes of various factors are to be considered, and how they can be combined. Not all these combinations will later be analyzed as scenarios, for some of the progression types could be mutually exclusive, or "inconsistent". Only where there are no logical conflicts between certain progression types for all key drivers considered, and are consistent "packages" to be found. The scenario processors will then have to select which items from amongst these packages will in fact be examined. The consistency analysis shows the quality of the work up to that point: for if the drivers are too numerous, too imprecise or poorly selected, one may get an impossibly large number of selections, an unsatisfactory array of them, or none at all. In such cases it will be necessary to change the selection of drivers in Phase 2, possibly replacing some of them, establishing some of them as framework conditions, or eliminating some of them from the selection altogether.

If none of the packages are consistent, that package with the greatest possible degree of consistency is selected, and the inconsistencies are adapted so that non-contradictory packages emerge. The consistency analysis is thus an aid for considering the relationship between certain key drivers.

2.5 Phase 5

Phase 5 represents the core of scenario development. On the basis of driver packages, so-called scenario "trajectories" are defined. The package with the trend extrapolation is, if appropriate, designated as the "trend scenario", or as "business-as-usual" (BAU). Each of the other trajectories receives a simple abbreviation designation, which, while it may not contain all assumed settings, at least identifies one important characteristic of that version of the future; these are called "archetypes".

The decisive step for the implementation of the KDF packages in scenarios is to recognize and to take into account – at least qualitatively – all essential effect quanta in landscape development, which, for reasons of operating practice, is carried out in pairs. This so-called "cross-impact analysis" (Kosow & Gaßner 2008) is often processed in the form of matrices, in which each combination of effect quanta to be taken into account can be noted. Models may depict complex contexts. As a result, a textual description will emerge, the so-called storyline, which should also include justifications. Tables or graphs are suitable for the preparation and as overviews. For later cartographic implementation, and for the assessment, a quantitative evaluation of essential indicators is useful. Care should be taken to determine whether preliminary determinations for the future can be derived from certain developments. These so-called "path dependencies" may result from the exhaustion of certain development, spatial, resource or other potentials which might prevent a later development of the same type from occurring. Often, one type among a number of competing technology lines will end up predominating, and then become the exclusive choice, while others are abandoned.

Rare but consequential single events which considerably confuse a draft scenario for the future can be very interesting. These so-called "wildcards" (e.g. an international bank crash) should be discussed separately from the rest of the scenario development, since they may be important for purposes of precaution, but are often rejected by participants due to their minimal probability. That means that scenario development should first of all be run through to the end without breaks, and wildcards could, if appropriate, be applied afterwards. The wildcard can be "played" at a defined point in time in the scenario run. From this point on, the story line can be rewritten, based on this event, or the model parameter established anew; see Figure 1. The use of wildcards very clearly forces thinking to be oriented towards various alternatives.

A spatialization of the scenarios is indispensable for the ensuing ESS assessment. For this purpose, the potential mapping procedures in Phase 4 are used. This results in the creation of cartographic drafts of future landscape conditions which represent an important test for the quality of the scenarios on the basis of the spatial compilation of particular statements. For this purpose, the Land Use change Modeller (LUMO) has been developed. This GIS-based method permits the localization of certain use changes, or the certification of preferred areas for secondary use and for ESSs, on the basis of stipulations in the scenario storyline. In the LUMO, a distinction is made between the certification of a) development regions, b) area-based changes, c) linear changes, and d) levels of intensity of farming.

In the LUMO, the rules for establishing trend scenarios differ from those for establishing alternative scenarios, due to the different databases and information on landscape development, which is available in such forms as prognoses, or landscape, regional or statewide development plans. This can provide the basis for statements on landscape development based on trend extrapolations, or for the provision of geo-information. Sometimes, however, rules must be set up even at this stage, as is the case for alternative scenarios, if the scenario version exceeds the timeline of the planning process or the prognoses, or if the contents of the scenarios are not covered. The LUMO consists of the following four modules A through D, which, depending on the issue at hand, can be applied singly or in combination:

Module A: Examines the development of residential and transport areas

Module B: Examines the development of agricultural spaces

Module C: Examines the development of spaces of open country with no agricultural use (e.g., nutrient-poor grassland, rocky fields, dwarf-shrub heaths, or ruderal and herbaceous fields)

Module D: Examines the development of regions with regard to their touristically and economically relevant changes.

2.6 Phase 6

In Phase 6, the evaluation of the storylines, tables and maps is carried out on the basis of the ESSs. Depending on how spatially concretely the scenarios have been depicted, they may be evaluated out either spatially differentiated, or non-spatially, on the basis of expert descriptions and statistics. This involves not primarily maps of certain services; rather, this stage is designed to reveal the interactions of services, their so-called trade-offs (Bastian et al. 2012) and synergies. For this purpose, risk and suitability areas are certified. The main goal of this work stage is to draw conclusions regarding the scenarios. It is not the selection of the best storyline that is central here; rather, it is which conditions – i.e., KDFs and their progressions – will lead to the desired developments, and which measures will be useful for achieving that goal. For this purpose, this work step is the one with the highest potential for participatory work. If suitable control instruments are identified during the discussion, it may be necessary to rethink the scenarios on that basis.

Based on a juxtaposition of the scenarios with the actual condition, there follows an accounting of landscape transformation based on selected indicators by the scenario team (s. Table 3). The changes may be statistically evaluated and visualized on the basis of a landscape barometer (Holfeld et al. 2012). Using the fundamental questions – the key question and the core issues – as the point of departure, recommendations for action should be yielded by the scenarios and their assessments. This step is differentiated by target group, as many international studies have impressively shown, e.g. TEEB (2009), or MA (2005). This demands that there be an exact definition of whom the options for action are to be directed towards. On this basis, the preventive and reactive measures can be derived for those addressed. The framework for this step is presented in Bastian et al. (2013).

2.7 Phase 7

Phase 7 includes all measures for the communication and participation of the scenarios with the actors (or the project principal). In spite of its highest number, this work step starts at the very beginning of the development of a scenario, and continues unbroken throughout the entire methodology. However, there can certainly be some switching back and forth between expert dominated work steps and those with greater public participation (so-called loops; cf. Walz et al. 2007), in order to quantify the opinions, translate expert knowledge into generally understandable forms, and give the scenarios a high degree of acceptance by means of broad public participation. In cooperation with experts and stakeholders, a number of participative approaches was tested. The recommendations are summarised in Syrbe et al. (2013).

The possible forms of results' representation are numerous, ranging from verbal through visual to interactive forms of depiction, and depending on target groups and goals. Particularly effective forms would include e.g. pictures, videos, model landscapes, newspaper articles and sketches.

3 Results

This article presents the results for the phases of scenario development all the way to the formulation of the storyline and the cartographic depiction for a selected core issue. We will only enter briefly into a representation and discussion of the results of Phases 6 and 7, since these are the objects of papers on participation and communications methods by Syrbe & et al. (2013), and the observations of the assessment methodologies for ESSs by Holfeld & Rosenberg (2012).

3.1 Phase 1: The key question and core issues

After the establishment of the key question: "How will landscapes in Saxony and their ecosystem services develop through 2050?", the project team carried out a brainstorming process, in which the core issues "biodiversity" and "renewable energies" were identified as particularly relevant for the future development of the landscapes in Görlitz district. In the following, the process of scenario development will be described using the example of the core issue "biodiversity" in the district.

3.2 Phase 2: Drivers and ESSs

Two catalogues have been developed as the basis for the selection of effect quanta and ESSs. The general driver catalogue is broken down into four categories: social, political/legal, economic, and ecological. In this catalogue, the relevant drivers for landscape change are compiled and briefly characterized, especially with regard to indicators, effective mechanisms, control possibilities and relevant actors. The catalogue of ecosystem services contains the possible indicators and assessment methods. Both catalogues must be modified and expanded in accordance with the key question and the respective core issue. There can be no such thing however, as an overall comprehensive catalogue which always characterizes all current drivers and processes from the global to the local levels.

Twelve drivers from the general driver catalogue have been identified as relevant for the core issue biodiversity, and underpinned in a specified catalogue with definitions, indicators and trends (Table 1). For this purpose, the project team has analyzed the development on the basis of statistical key values such as e.g. agriculture and forestry statistics (Statistisches Landesamt des Freistaates Sachsen 2011), farm subsidies by the Common Agricultural Policy (CAP) (Europäische Kommission 2012), Renewable Energy Law subsidies (EEG 2008), and forest increase planning (Upper Lusatian/Lower Silesian Regional Planning Association 2010). Moreover, a change analysis based on biotope type and land use mapping (BTLNK) processes of 1992-93 and 2005 (SMUL 1992, 2005) has been carried out. The comparison between the two land-use mapping processes shows a growth in area of 73% for "long-term fallows", 60% for "woods and shrubs", 40% for "bodies of water", and 33% for "rocky fields and dwarf shrub heaths". On the other hand, there are major area losses of 78% for "farm maintenance land", 61% for "fallow farmland", 43% for "landfill, waste and excavation areas", and 27% for "transport and infrastructural areas".

3.3 Phase 3: KDFs and framework conditions

The drivers selected in Phase 2 were incorporated into the relevance analysis in which those KDFs were ascertained which are to lead to the differentiation of the scenarios for the core issue (Table 2).

Table 1: Characterization of drivers in the specified driver catalogue (excerpt)

Issue area	**Driver**	**Brief description**
Cultural and societal value	Lifestyles	The social dominance of value concepts or behaviour patterns with impact on consumer behaviour, political involvement and land-use, such as consumer associations, organic/slow-food consumption, individual mobility (car-sharing, public transport, bicycles/e-bikes), and regional/local networks
Political control	Support for renewable energies	Renewable Energies Law (EEG), Biofuel Quota Law (BioKraftQuG), Biomass Power and Biofuel Sustainability ordinance
	Support for agriculture and landscape care	Support of agriculture: 1st Pillar – Market order, direct payments; 2nd Pillar: development of rural areas, including agro-environmental measures, support programmes for landscape care, gentle use, restructuring and specific measures for species protection
	Forest expansion programmes	Efforts to increase the forest proportion, supported by promotion of reforestation of previously agriculturally used areas.

Table 2: Presentation of the key drivers and their issue areas

Issue area	**Key driver**
1. Cultural and societal values	• Lifestyle
2. Political control	• Support for renewable energies (currently via the EEG) • Support for agriculture (CAP, especially ecological priority areas) • Forest expansion programme

The other eight drivers were established as framework conditions for the core issue “biodiversity”; they were not to be differentiated for various scenarios. They were: climate change, demographic change, development of natural site factors (water balance and soil properties), proportion of protected areas, intensity of land use, and demand and exploit ability of raw materials (especially brown coal and copper ore).

3.4 Phase 4: Description of KDFs and their types of progression

For each Key Driving Force (KDF), three development lines were designed and characterized more precisely in a profile. The results flowed into the analysis of the consistence of the type of progression, in order to ascertain a consistent KDF package. From one of these packages, the traditional eco-scenario was drafted and also a contrasting scenario which we designated the “technology-energy scenario” (Figure 5).

3.5 Phase 5: Storyline of the trend scenario

The results of the trend scenario are shown here as an example for the formulation of the storyline and the cartographic localization of use change. It was developed in a workshop together with various professional and volunteer actors from the areas of planning, nature conservation and education in Görlitz district, and has been supplemented by additional research (trend analysis).

Here, excerpts from statements on the first KDF, “lifestyle”, are shown. Quantifiable developments which can be localized on a map are described comprehensively on the bases of several essential indicators for the three scenarios in Table 3.

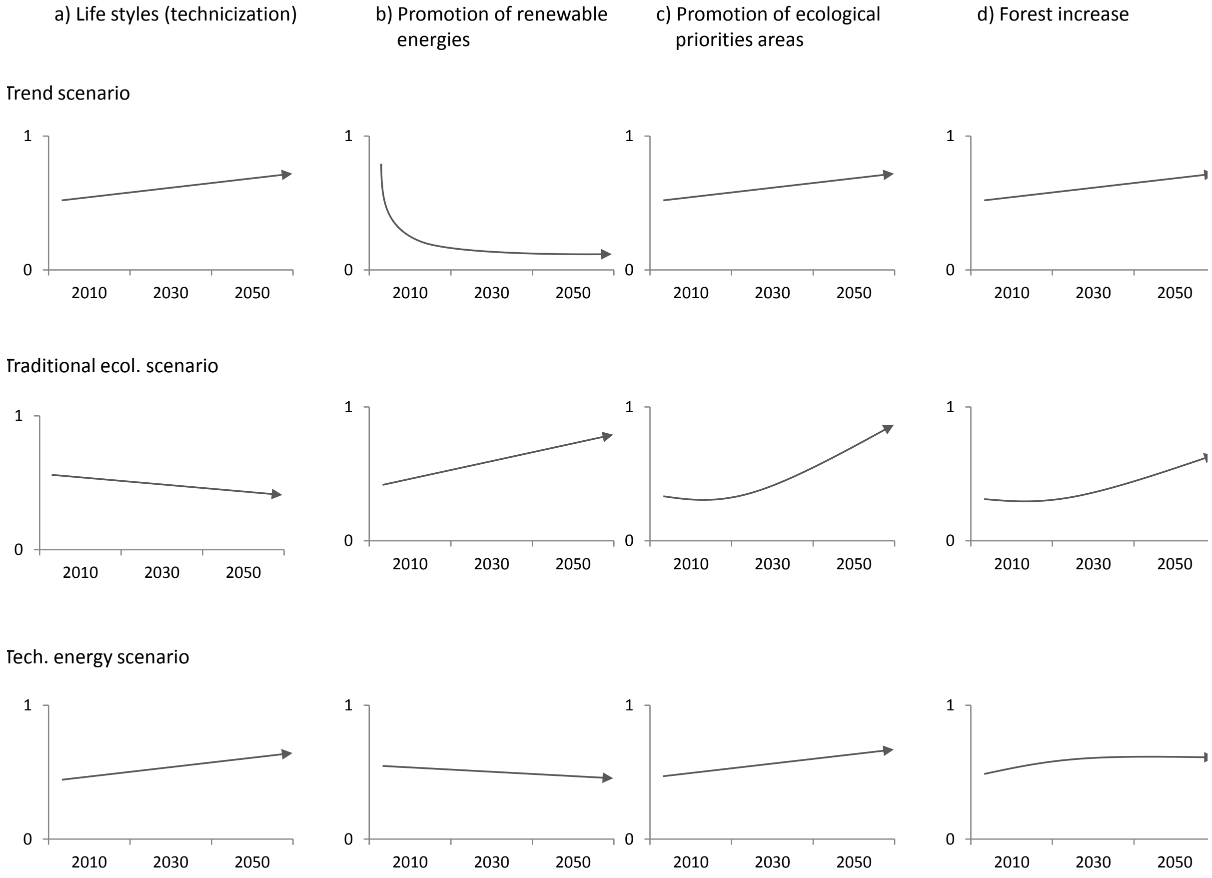


Figure 5: Representation of the progression types and KDF for the trend and alternative scenarios

Storyline cultural and societal values: Lifestyles (traditions, regional identity)

“The demographic and economic development is leading to a further segregation of the population with regard to employment, income and social conditions. Especially well-educated, female young people are continuing to emigrate from the district. During the period through 2050, this will lead, in all age groups, to the loss of competent and committed inhabitants who could identify with the region and thus strengthen regional development. Increasingly, it is older people who live in the district. Nonetheless, dependence on technology and energy is increasing, for the faith in the ability to manage everyday matters by means of technology is becoming ever more dominant, with the change of generations. This is occurring at a time of a global shortage of certain resources, such as copper, and hence is leading to a drastic increase in market prices. Ownership of mobile telephones and computers is becoming normal for all generations. The effect of the media, the conscious filtration of information from the flood of daily events, is leading to the increased manipulation of uncritical groups of the population. The connection to nature and knowledge of various natural processes is declining, since these contexts are being reflected ever less. Ever more tourists are visiting the district, which is increasing in attractiveness as a result of the diversity of its natural spaces and its cultural attractions. Well educated senior citizens are moving to the city of Görlitz, since rents are cheaper there and age-appropriate infrastructure is being developed. These inhabitants are involving themselves in the social life of the city, and strengthening it through their volunteer activities. Nonetheless, local government is ever less financially capable of supporting cultural and social infrastructures.

Young families occasionally move into the district and young people who had previously emigrated are moving back, since real estate is favourably priced here and also because of their ties to their old homeland. In doing so, many consciously risk insecure income situations; however, their interest in life in this region is the dominant factor. In some rural areas, this is leading to the preservation of agriculture for subsidiary income, which provides a contribution to the care and preservation of the cultural landscape.

The growing shortage of natural resources and the increasing environmental problems, such as drought, flooding, soil degradations or epidemics, is leading to stronger policy regimentation as to the type and intensity of certain land uses. The consciousness for organically grown food and the demand for transparency in the food business have grown as a result of a number of food scandals, and have led to a transformation of agricultural production. A strong orientation for the preservation of ecological functions has led to a reduction in nutrient immission into the water, and to an improvement of soil protection.

Continued mining of coal and copper is still accepted by the population of the region, in spite of its environmental effects, since there are no employment alternatives. With the expansion of the opencast mine at Nochten, the lifespan of the Boxberg Power Plant has been secured through 2050. There will be no more opening of further opencast mines, since there is no support in the population for that."

Certification of use change in concrete areas or in certain regions was carried out with the aid of the LUMO regulations, and using the results of the cross-impact analysis. Table 4 shows those use categories for which changes are expected under the scenarios. The result of the modelling is represented for the trend scenario in Figure 6. An animation of all scenarios is presented in Figure 7.

Table 3: Representation of the scenarios and of the indicators derived from the KDFs

KEY DRIVING FORCE	TREND SCENARIO		ALTERNATIVE SCENARIOS			
			Traditional ecol.		Techn. energy	
	2030	2050	2030	2050	2030	2050
Lifestyles (traditions, regional Identity)						
Demand for organic food	↗	↗	↗	↗	→	→
Technologization of everyday life	↗	↗	↘	↘	↑	↑
Agriculture						
Organic agriculture	**6%**	**10%**	**50%**	**100%**	**5%**	**5%**
Ecological priority areas	**7%**	**10%**	**7%**	**10%**	**4%**	**4%**
Energy crops	↗	↗	→	→	↑	↑
Forestry						
Proportion of forested area	**35.7%**	**36.5%**	**36.5%**	**38%**	**35.5%**	**35.5%**
Mining						
Amount of brown coal mined	→	↘	↘	↘	↗	↑
Amount of copper mined	↗	↘	**0**	**0**	↑	↑
Renewable energies						
RE share of total power	**58%**	**71%**	**65%**	**100%**	**40%**	**50%**
Economic development						
SME start-ups	↘	↘	→	→	↗	↗

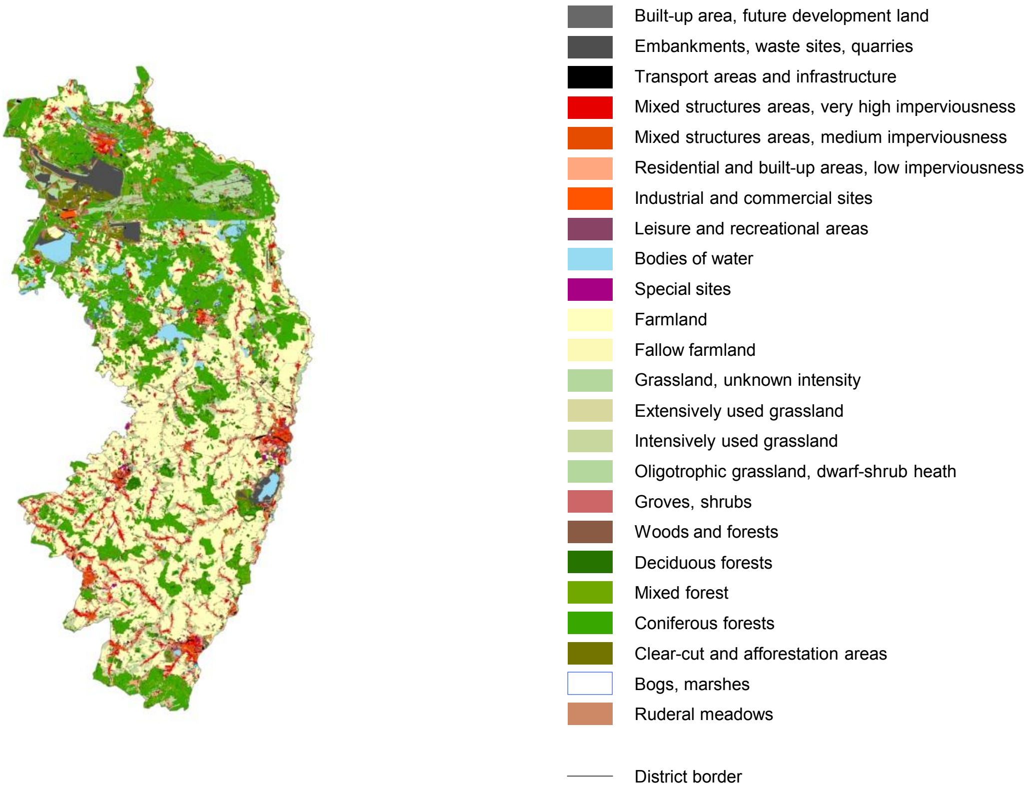
RE - Renewable energies; SME - small and medium enterprise

Table 4: Presentation of the spatial, localizable use changes in the scenarios

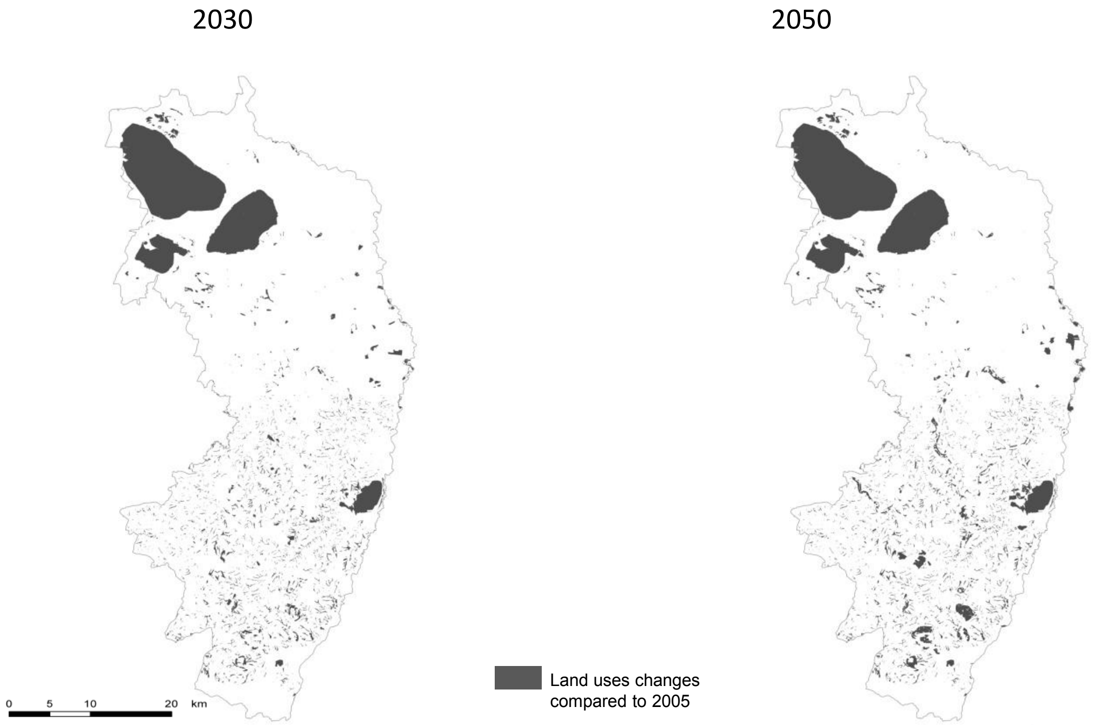
Transformation of (row) to (column)*	**Arable land**	**Grass-land**	**Forest**	**Eco-priority area**	**Water**	**Open-cast mine**	**Wind-power plants**	**Fallows**
Arable land		+	+	+	-	+	+	+
Grassland	-		+	+	+	+	+	-
Forest	-	-		-	-	+	-	-
Eco-priority area	-	+	+		-	+	-	+
Water	-	-	-	+*		-	-	-
Open-cast mine	+	+	+	+	+		+	+
Wind-power plants	+	-	-	-	-	-		+
Fallows	+	+	+	+	-	+		

*Explanation: E.g., conversions are expected from arable land in grassland in connection with Greening measures to GAP 2014; the reverse dynamism, namely ploughing up of grassland to arable land is prohibited according to EU right and federal state law.

Land use, 2005



Trend scenarios



Data:
- ATKIS VG 250 (2008): Federal Agency for Cartography and Geodesy.
- Biotop and land use types (2005): Saxon State Office for Environment, Agriculture and Geology

Map: M. Rosenberg, 2012.

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Figure 6: Actual condition of land-use, and trend scenarios, 2030 and 2050

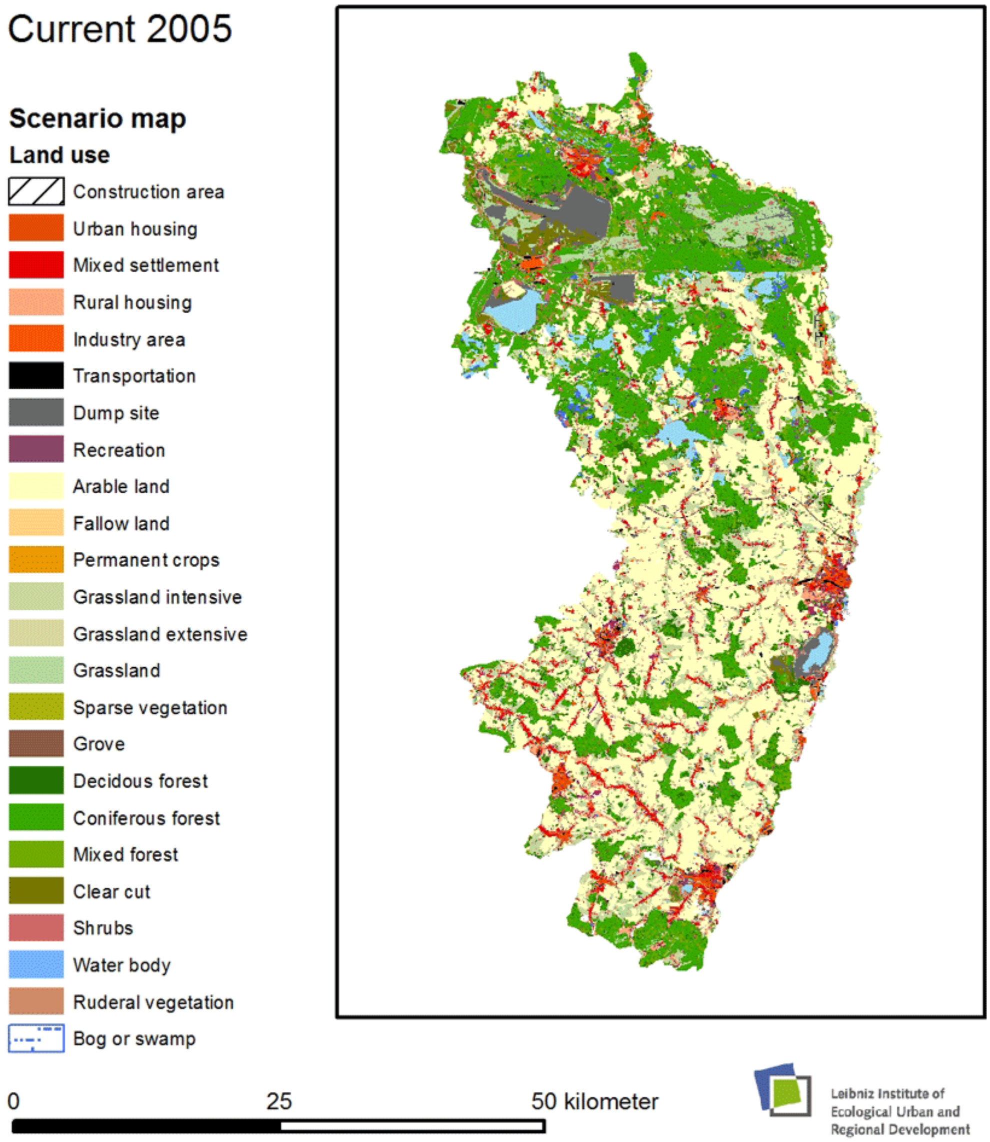

Figure 7: Representation of the actual land use in 2005 and the three scenarios
Basic data: Biotop and land use types (2005): Saxon State Office for Environment, Agriculture and Geology , Map: M. Rosenberg, 2012.

3.6 Phase 6: Evaluation of the scenarios

Based on the qualitative and quantitative changes in Görlitz district as formulated in the scenarios, an assessment of landscape change according to the EES as selected in Phase 2 was carried out. This permitted a comparison of values of the scenarios with the initial condition, and with one another (Holfeld et al. 2012). In the following, only the changes in use are shown, using the example of the trend scenarios. In the mining areas, re-cultivation measures are compensated for by the continuation of opencast mining. An increase in forest areas by 2% through 2050 involves primarily the steep slopes strongly in danger of erosion. As a result of CAP subsidies, the share of ecological priority areas will increase by 7% between 2014 and 2030, and by 10% through 2050 where farming is to be abandoned along the depression lines, on steep slopes and also in selected core areas and corridors of the Saxon biotope networking plan. These areas will then be used as permanent grassland, for the planting of hedges and groves, or will remain fallow.

Renewable energies will provide 58% of power production by 2030, and 71% by 2050 (Prognos AG 2011). This will be made possible primarily by the expansion of wind power and biogas facilities. Overall, the number of wind power plants in Görlitz district is to increase from 123 in 2010 (rated output: 180 MW) to approx. 112 in 2030 (rated power: 260 MW), and then drop to approx. 80 in 2050 (rated output: 350 MW), with the increased output being due to repowering. That will mean that approx. 500 GWh per year of wind power will be produced in 2030, and approx. 720 GWh in 2050. The number of biogas plants will also increase, although the increase will slow down with increased competition for space, and with a slow exhaustion of commercial fertilizer and wastes. In addition, there will also be mostly small cogeneration plants of up to 700 kW_{el}. It is assumed that by 2030, approx. 60 biogas plants will be online. Moreover, an additional 3 to 5 large bio-methane feed-in plants using stock-based substrates with residue utilization are to be built, with an output of 2 to 5 MW.

In addition to the inevitable loss of biodiversity through the mining of coal and through intensified farming, there will also be an overall improvement of ecological functions due to measures for structural enrichment and removal of land from agriculture.

3.7 Phase 7: Communications and participation

Using various participation methods (Syrbe et al. 2013), important actors in the district have been developing the trend scenario in several workshops together with experts from the project team. In selection of the participants, it was seen as important to have a broad thematic background appropriate to the selected core issue “biodiversity”. The alternative scenarios and the GIS-based localization of utilization change were developed by the project team. As the scenario exercises showed, the methodology is suitable for the development of the landscape scenarios with an integrated assessment of the ESSs involving a smaller circle of experts and a larger number of stakeholders. In addition, it is open for the consideration of various core issues, drivers of landscape development and ESS assessments.

4 Discussion

When addressing landscape change, it is necessary due to the large numbers of direct and indirect driver, to deal with a multi causal network of them, in order to ascertain those factors which are of the greatest significance for the selected core issue (Höchtl et al. 2006, Klijn 2004). Nassauer et al. (2002) actually began the Internet-based identification and coordination of drivers prior to the beginning of the actual workshops. Such pre-coordination proved to be useful in the present study as well, although we worked with questionnaires which were sent out, rather than with list servers.

In the application example, for the assessment of the effects of landscape scenarios on biodiversity, not only such direct drivers as climate change and use intensity, but also such indirect drivers as demographic change and cultural, economic and socio-political factors were taken into account, which are, according to MA (2005) the responsible impulses with regard to change in biodiversity and ecosystems (cf. also BMU 2007). Santelmann et al. (2004) derive their biodiversity scenario primarily from land use and forestry policy. In Nelson et al. (2009), demographic development was added. The GEO scenarios (UNEP 2007) also incorporated societal value change and scientific-technological innovations. If too many factors are incorporated into the development of scenarios as KDFs, not only is the effort required greatly increased, but the overview and the communicability of the scenario is also hampered. For this reason, the authors of the presented application example have limited themselves to the four most important KDFs for the selected core issue.

Albert (2009) is among those who demand that one proceed participatorily from the outset in scenario development, i.e., that one integrate stakeholders in all scenario stages, and that the groups of actors thus be distinguished. One result is that the number of KDFs must be kept to a minimum. Moreover, most participatory approaches address a lower number of KDFs – usually two or three (Rotmans et al. 2000)

– than do the expert scenarios based on models, where the number is often five or six. However, it is possible to move away from the concept of KDFs by e.g. predetermining the direction of the scenarios through the selection of the actors, as was done by Hulse et al. (2004).

The development of scenarios with the aid of the participation of various stakeholders with varying expert backgrounds and experience with scenario exercises is a time-consuming and high-effort process for the team which is to prepare and accompany the scenario exercise. However, the scenario development process also gains more information through improved regional and local knowledge on the part of the participants, as other investigations, too, have shown (Reed 2008). The participation of the authors in other scenario exercises (Demuth et al. 2010, Priess & Hauck 2011) outside the project have shown how difficult it often is for the participants to develop scenarios freely and independently of the trend, or to carry out an exchange regarding wildcards. This also results from the particular professional backgrounds of the participants, and their willingness to engage in discussions. For the development of scenarios, it is therefore necessary to undertake a training session of participants with regard to the development of scenarios. Since there was no time for several day workshops in the application example, only the trend scenario was developed together with the stakeholders. The development of alternative scenarios was carried out in the project team.

What has hardly been explicitly handled to date is the question of the spatial concretization of scenarios. For this purpose, Verburg et al. (2010) selected a regional clustering of European districts, involving the stakeholders in participatory projects (e.g. Hulse et al. 2004). Fritsch (2002) used a set of rules for the purpose of spatialization. Our own set of rules for deriving future land-use structures (LUMO) was first of all applied for this trend scenario, and later, too, for the alternative scenarios. Here, it was shown that especially the cross-impact analysis was of importance, since a number of areas often showed potential for differing follow-up uses (e.g. forest increase, or ecological priority areas). This in turn had an effect on particular ecosystem services, since the type and structure of land-use decisively affected the development of the ecosystems (Spangenberg 2007) and their species diversity (Michel & Walz 2012). Here it is important, to discuss the priorities of follow-up use in expert teams, and to establish selection criteria. Often, planning is carried out with the reference to particular areas of expertise, so that measures and areas are selected from the perspective of particular use categories, such as the development of residential areas, from the perspective of village or urban development, and without equally taking into account the priorities of other use types, such as the site potentials for agriculture. However, the approach presented here combines the three sectors under consideration of competing use potentials, in order on the one hand to depict all spatially relevant land-use changes, and also the multiplicity of use claims.

For the evaluation of ESSs, it is necessary to find quantifiable indicators, and for that purpose, data in sufficient temporal and spatial resolution so that a basis for the allocation of use change and modelling of various ESSs is possible. These data can however not always be made available in sufficient quantities (Holfeld et al. 2012). For this reason, only those ESSs and/or assessment methods such as InVest (Integrated Valuation of Ecosystem Services and Tradeoffs) (Holfeld & Rosenberg 2012) have been considered in the present application example which can be reliably parameterized on the basis of the available data.

5 Conclusions

The methodology presented here was developed and tested in the project Landscape Saxony 2050, and has now also been used in other projects with scenario tasks. After an intensive introductory explanation of the scenario methodology, the participants engaged in discussions at workshops in a very goal oriented manner, so that even difficult questions, such as those involving the spatial impacts could be handled very well. In the example area, scenario changes brought actors from a variety of areas of expertise together, so that interdisciplinary concepts for landscape development and unconventional strategies could be exchanged.

For the development of the scenarios, a precise definition of drivers was essential. On the other hand, viewing entire issue complexes, e.g. the development of the energy industry or of the mining industry, then precluded any further precise processing. The experience of the project shows that more than four key drivers can under no circumstances be recommended, and that ultimately, only two or at most three distinct drivers really make sense, or can be observed in their interactions. Generally, the time required for the drafting of scenarios is reduced with the number of drivers, the involved stakeholders, and the substantive scope of the core issue.

The integration of ESSs has brought new aspects into the scenario technique, but has on the other hand increased the complexity of the procedure. Simplification steps must therefore also be addressed; they may be provided by other application tests in other regions and on alternative core issues. Currently, a visualization possibility, the landscape barometer, is being tested. It is to be able to depict the assessment of the ESSs of particular scenarios and make them comprehensible to a broad public. An operationalization of the set of rules for the purpose of spatialization of use change in the form of a GIS extension is being considered.

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