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ECOSYSTEM SERVICES AND ENERGY CROPS — SPATIAL DIFFERENTIATION OF RISKS

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Abstract

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The increased cultivation of energy crops has a variety of economic, social and environmental effects, which can be assessed using the concept of ecosystem services (ES). Among the various instruments for regulating energy crop cultivation, reducing the impacts on ecosystems and landscapes, and moving sustainable land management forward, the ES concept is a useful tool since it includes economic, ecological and social aspects. The methodological approach is exemplified by a case study in the district of Görlitz, Germany. It started with an indicator-based analysis of the present state of landscape functions or services, focusing on the "supply" part of ES assessments. The results were interpreted in light of an ecological risk assessment concerning intensified agriculture in general and the increased cultivation of energy crops in particular: on the one hand for the present situation, and on the other, for three different future scenarios. It was possible to project the results onto reference units (biophysical units), and to reveal spatial differences in carrying capacity or sensibility as a result of increased energy crop cultivation. The demand side of ESs was assessed on the basis of semi-structured interviews and standardized questionnaires.

Key words: biodiversity, carbon sequestration, landscape units, preference analyses, risk assessment, scenarios.

Introduction

The rapid world-wide development of energy crop cultivation has a variety of economic, social and environmental effects. Threats to ecosystems and landscapes, such as impacts on the groundwater, soils, biodiversity and the overall appearance of the scenery, are becoming ever more obvious (e.g. Rode et al., 2005; Bastian, Schrack, 2007; Lupp et al., 2011); hence, there is an urgent need for suitable instruments to regulate energy crop cultivation and reduce the impacts on ecosystems and landscapes. As this includes economic, ecological and social aspects, we see the concept of Ecosystem Services (ES) as a stimulus and as a suitable tool for assessing the impacts – the ancillary effects – of biomass production for purposes of energy production, and identifying appropriate steering instruments, e.g. such regulatory measures as planning tools, legislative regulations or incentives, and also economic instruments and management systems for sustainable biomass production.

Using the example of the district of Görlitz, in the German state of Saxony, we assessed both the present state of selected ecosystems and ESs, and their expected situations under three possible scenarios of energy crop cultivation, in terms of the following factors: yield potential or biotic productivity of the site, soil erosion (water, wind), nitrate leaching, groundwater recharge, carbon sequestration, habitat function, and landscape aesthetic values/recreation. Within the ES cascade (Haines-Young, Potschin, 2009; Bastian et al., 2012), this step represents the supply side. Particular importance is attached to regional differentiation within the study area on the basis of physical units. To cover the demand side, surveys (semistructured interviews, standardized questionnaires) were conducted among stakeholders and inhabitants of the Görlitz district. From the broad spectrum of economic valuation methods, elements of stated preference analyses and contingent valuation (willingness-to-pay) were chosen.

Methods

Study area

The district of Görlitz has some 275,000 inhabitants and an area of approx. 2106 sq km; it is located at the tri-national border with Poland and the Czech Republic. It is characterized by a wide variety of physical regions (macrochores, Fig. 1) typical for Central Europe. In its northern lowlands, the district includes old moraine landscapes with minimal soil quality and low water storage capacity. Loess and sandy loess hilly areas dominate its central part, while low mountain ranges mark the south. In the loess hilly landscapes, the fertile soils provide favourable farming conditions and enable the production of a wide range of market crops, such as wheat, barley and maize. The potential natural vegetation in the north is pine/ oak forest on groundwater-remote sites, and birch/ English oak forest on groundwater-proximate sites. Acidophilic deciduous forests, primarily beech, but also with lime, hornbeam and oak, are the dominant potential natural vegetation in the other areas. Agriculture occupies 96,000 ha (almost 46% of the

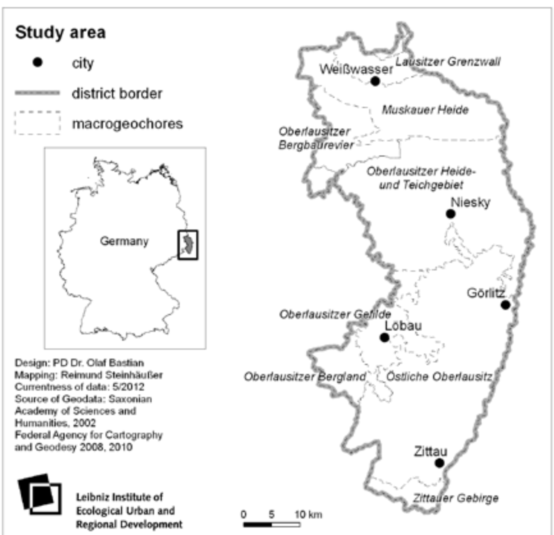

Fig. 1. The study area, the district of Görlitz in Saxony, with its physical regions.

Legend (original German names/English): Lausitzer Grenzwall/Lusatian terminal moraine; Muskauer Heide/Muskau heath; Oberlausitzer Bergbaurevier/Upper Lusatian mining area; Oberlausitzer Heide- und Teichgebiet/Upper Lusatian heath and pond area; Oberlausitzer Gefilde/Upper Lusatian loess hill area; Oberlausitzer Bergland/Upper Lusatian mountain highlands; Östliche Oberlausitz/Eastern Upper Lusatia; Zittauer Gebirge/Zittau Mts.

district), of which 20,000 ha (23%) are used as permanent grassland, and 38,500 ha (77%) as farmland; of the latter, in turn, approx. 50% were planted in cereals and 10% in silage maize in 2010 (Napp, Oettel, 2011).

Ecosystem assessment – the supply side

We started with an indicator-based analysis of the present state of seven ecosystem services (see Table 1) in the sense of the "supply" part of ES assessments. In order to estimate the unknown future effects of energy plant cropping, we preferred the way of risk assessment; the risk means that an ES is in danger to be impaired. The conception of environmental risks involves danger, vulnerability and site explosion in a clear scientific way and assesses the interaction between nature and society using the possibilities of (negative) impacts as well as (positive) chances for development (Schanze, 2006). Such a conception is particularly meaningful for scenario analyses.

The total value of a particular ES is determined in terms of the existing risk within physical units called microchores (cp. 3.2). Therefore, the values from Section 2.2 were averaged for each reference unit. In most cases, we defined five categories, from 1 (very low risks) to 5 (very high risks). To obtain an overall risk assessment for a package of selected ES, the sum of particular risks was calculated, these being erosion (water and wind together), nitrate leaching, groundwater recharge, carbon sequestration, habitat function and landscape aesthetic value.

The risks to ES supply were also estimated for three scenarios (Syrbe et al., 2013) of future energy crop production:

1) The current trend: continuation of the current trend of intensive agriculture and energy crop cultivation, with increased use of firewood from the forests.

2) Diversification: more diverse solutions for agriculture and biogas production, more nature conservation, a more diversified landscape.

3) Intensification: large-scale intensification and homogenization of land use (agriculture, forestry), on the poor sites in the north of the study area; large short rotation coppices on farmland.

We graded the effects of the scenario-based land use changes for ES as follows: 0: no change (constant); +1/+2: slightly/heavily, increased risks (worsening of the present state of ES); -1/-2: slight/strong decrease in risks (improving state for ES).

The total risk (for the bundle of ES listed above) was classified as follows: Risk class +2 (sharp deterioration): Increase in risks by at least 4 points (from the sum of the single risks); risk class +1: +2 to +3 points, 0: -1 to +1 points, -1: -2 to -3 points, -2 (strong/ essential improvement): - 4 points or less. In detail, we analyzed the supply of the following ES (see Table 1):

T a b l e 1. Analyzed ecosystem services with their definitions.

Ecosystem service	Definition
Yield potential	the capacity of the ecosystem to produce plant biomass by photosynthesis sustainably (= biotic productivity of the site)
Resistance to soil erosion	the capacity to withstand soil losses caused by human activities which exceed normal (natural) amounts (e.g. those due to mineralization processes, bedrock weathering etc.)
Resistance to nitrate leaching	the capacity to store nitrate in the root layer of the soil or to attenuate nitrate leaching processes
Groundwater recharge	the flow of percolating water to the groundwater, or the process of replenishing groundwater resources with infiltrated water
Carbon sequestration	the absorption of carbon from the atmosphere and its storage by soils and plants, which is an important factor in climate change mitigation
Habitat function	the capacity to supply favourable living conditions for a rich flora and fauna, biocoenoses and biotopes
Landscape aesthetic value/ potential for recreation (in the landscape)	the beauty, peculiarity and the capacity of a landscape to make nature-based recreation possible, i.e. relaxation, recovery, health, and enjoyment of the landscape in order to increase fitness, happiness and life-span, and thus satisfy the cultural and aesthetic requirements of society (cp. Haase, 1978, Bastian, Röder, 1998)

Yield potential: Important indicators include soil texture (size of soil particles), nutrient supply, amount of stones and humus, depth of soil, soil moisture, field-moisture capacity, groundwater level, relief (hill slope), and climatic factors (average annual temperature and precipitation, danger of frost, duration of the optimal growing season).

Resistance to soil erosion: The resistance against **water erosion** depends on the erodibility of sites and the erosive action of rainfall (natural or potential erosion propensity) as well as on the actual land use (actual erodibility). Erodibility of sites is a function of soil parameters (e.g. texture, content of humus and stones, humidity, infiltration capacity), relief parameters (e.g. hill slope and length) curvature, and soil cover (plants, land use etc.).

For **wind erosion**, Wind and precipitation parameters, soil class, soil structure (especially size and stability of soil aggregates), roughness of surface, length of field parcels along the prevailing wind direction, and soil cover by vegetation are important factors (Bastian, Röder, 1998; LfULG, 2007).

Resistance to nitrate leaching: The important parameters are the field capacity of the soils, the climatic water balance (precipitation, evaporation), the soil moisture, and microbial activity. The propensity of a site to nitrate leaching can be described as the exchange frequency of the soil water in the root layer, which depends on field capacity and infiltration rate. Nitrate inputs (e.g. by fertilizers) and heavy rainfalls can increase leaching (Bastian, Röder, 1998; LfULG, 2007).

Groundwater recharge: Important parameters include climate, water balance, soil and bedrock characteristics (effective field capacity, effective rooting depth, groundwater table in hydromorphic soils), relief (slopes), land use or vegetation cover, and the morphology of running waters. Groundwater recharge corresponds with the infiltration rate, which is a measure of how much water leaves the root layer of the soil.

The values for yield potential, risks of/ resistance to soil erosion (water, wind), nitrate leaching risks and groundwater recharge were taken from the Soil Atlas of the State of Saxony (LfULG, 2007).

Carbon sequestration: The characteristics of various soil and vegetation types determine how much carbon is taken up from the atmosphere and how much is released into it (MA, 2005). Especially bog and hydromorphic grassland soils store large quantities of carbon in the upper soil layer (0—0.3 m). Disturbances such as drainage and tillage may change the microbial activity, mineralize these carbon stores and release them as CO_2 into the atmosphere. The highest carbon losses can be caused by drainage and ploughing up the grassland, especially on fragile hydromorphic sites. The destruction of these ecosystems results in the release of large quantities of carbon into the atmosphere, thus contributing to climate change (Saathoff, von Haaren, 2010). To assess the risks for carbon sequestration, peat and semi-terrestrial soils (various types of clays) were identified according to the Soil Atlas of Saxony (LfULG, Fig. 2).

Habitat function: The habitat function is an extremely complex variable. Indicators include rarity/ endangerment, naturalness/hemeroby, diversity, age/development time-span or regenerative capability of vegetation units or ecosystems, and spatial (bio-geographical) aspects (minimum size, arrangement of ecosystems, their isolation, connectivity, and biotope linking systems, ecotones) (Bastian, 1992). In essence, the analysis and interpretation of habitat values can be obtained by studies at several levels of investigation, ranging from detailed fieldwork approaches to surveys in large territories, using existing data. For large study areas like the district of Görlitz, already existing data are used, particularly the size and distribution of strictly protected areas (nature reserves, biosphere reserve, Natura 2000) as an expression of the biodiversity value of a region. The impacts of increased energy crop cultivation on various biodiversity indicators (e.g. birds – especially the sky lark, but also segetal weeds) were assessed by data from the literature (e.g. Dziewaty, Bernardy, 2007).

Landscape aesthetic value: Protected areas (particularly landscape protection areas), large forests and waters (ponds) are an expression of the landscape's aesthetic value. Intensive agriculture in general, and especially biomass cropping, manifests itself in monotonous landscapes (dominant maize fields) and in reduced free views (tall maize plants, short rotation coppices).

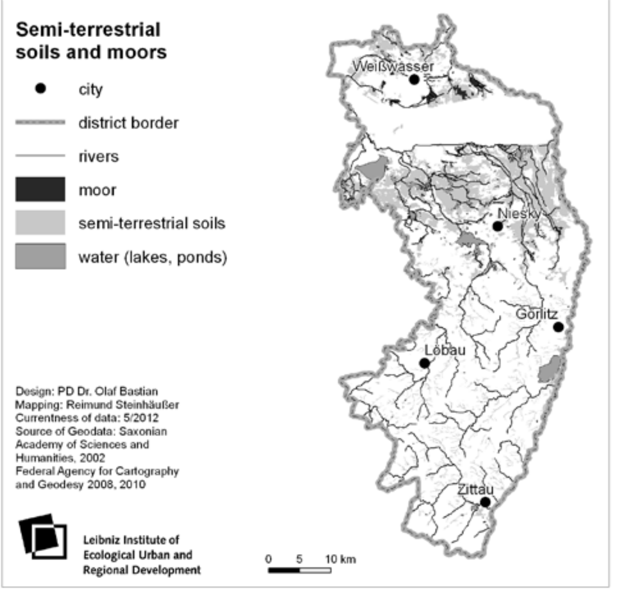

Fig. 2. Semi-terrestrial soils and peat soils in the district of Görlitz.

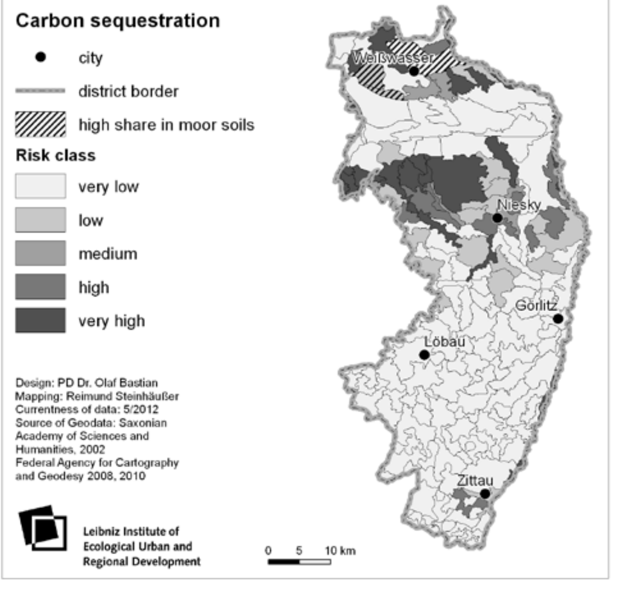

Fig. 3. Actual risks for carbon sequestration in micro-chores of Görlitz district.

Regional differentiation

The ES assessments (supply side) were related to reference units to better express and depict the various impacts of energy crop cultivation, depending on the specific characteristics of the various physical landscapes in the study area.

The natural or biophysical unit (in German: Naturraum) is an area of land – a section of the earth's land crust – characterized by a specific structure type of natural conditions; it is the result of the interaction between the geosphere and the biosphere (Haase, Mannsfeld, 2002). In other words, the biophysical unit is that part of a landscape which is determined by conformable natural components: geological and geomorphologic structure, soil, water, climate, flora and vegetation, and fauna. There are also several other names for such entities, e.g. geocomplex, natural complex, natural sphere, geo-chore, land unit, land system and eco-region (Bastian et al., 2006).

Landscape units can be aggregated at various levels of abstraction, resulting in a number of sub-dimensions within the so-called chorological dimension: nano-, micro-, meso- and macro-chores (choros: Greek "space", "land"). In the chorological dimension, we thus have to move away from the concept of homogeneity that has been originally used to define ecotopes (Neef, 1963). At the chorological level, the certainly existing internal heterogeneity is reduced to generalized information, which is defined as homogeneous at a higher level of abstraction (Herz, 1973; Löffler, 2002).

As reference units in this study, we used different landscape complexes: large scale physical regions, so-called macro-chores, and physical units of a smaller spatial extension at the level of micro-chores (Figs 3—5).

Micro-chores are mosaics of ecotopes. On average, they consist of 80—100 geotopes which, in most cases, can be assigned to 12—15 different types (geoforms). The pattern of topes in micro-chores primarily reflects the landscape-genetic conditions (natural history) or their development and succession. Micro-chores in Saxony range from 3 to 30 km^2, and have an average size of 12 km^2 (Bastian, 2000). They are characterized by the following key indicators: geological-structural unit, meso-relief mosaic type, soil form combination, area type of hydromorphy, macro-climate and altitude zone.

An inventory and classification of biophysical units at the level of micro-chores is available for the whole State of Saxony. This is the result of a landscape classification project (Bastian, 2000; Haase, Mannsfeld, 2002), which identified 1462 micro-chores covering the entire state (total area: 18,338 km^2). They were classified into 169 types, according to their dominant characteristics, such as relief, soils, and water balance.

Standardized interviews: The demand side

To complete the ES assessment, it is necessary to consider the demand side, which includes a high level of participation. Hence, practitioners have been involved intensively in the valuation process. In a first step, together with key stakeholders such as farmers, planners and agricultural authorities, we identified relevant core ES to be examined thoroughly in further steps using a world-café approach (Brown, Isaak, 2005). These stakeholders addressed as the most important ES food and feed production, soil fertility and ecology, provision of biodiversity and ethical values.

To gain insights into the attitudes of relevant key stakeholders, a qualitative approach using structured interviews was carried out. To survey farmers we used the method of semi-structured interviews (Marshall, Rossman, 1998), under which farmers to be interviewed were selected according to the principle of maximum contrasts (Hunziker, 2000), so as to encompass the attitudes and opinions of all types of farms in the Görlitz district. Through mid-May 2012, twelve representatives from the various types of farms – large cooperatives, small family owned, and organic as well as conventional farms – were interviewed. Finally, a quantitative approach was chosen to survey attitudes and opinions of the residents of the study area. We used standardized interview sheets and face-to-face interview situations at three locations in the study area, where interviewers could question c. 250 passers-by at frequented places.

Results

Current state of ecosystem services

The assessment of the current state of selected ES (supply, risks) produced the following results:
Yield potential: There is a clear division of the Görlitz district into three sections: On the poor sandy sites in the north, the yield potential is very low; this section includes the Lausitzer Grenzwall, the Muskauer Heide, the Oberlausitzer Heide- und Teichgebiet. The potential is likewise low or very low in the very southern Zittauer Gebirge. In contrast, high to very high yields are possible in the middle and in the loess covered areas of the south; this area includes the Östliche Oberlausitz, the Oberlausitzer Gefilde, and, to a lesser extent, the Oberlausitzer Bergland.

Resistance to soil erosion: With respect to the risks of erosion, a division into two areas is apparent: Mainly the hilly southern part of the study area (loess soils) suffers from water erosion, while the more flat northern part (peaty and sandy soils) suffers from wind erosion.

Resistance to nitrate leaching: Significant differentiation within the study area due to the interference of various soil and land use factors. Mainly the northern part with its exposed groundwater bodies (highly permeable surface layer of sand) is endangered by increased fertilizer applications. But also the southern part with its sufficient water and matter absorption capacity can be suffer from harmful nitrate transfers once the thin loess layer is completely eroded caused by higher farming intensities.

Groundwater recharge: The rather diverse mosaic of soil and land use characteristics cause a low potential in the Muskauer Heide because of the forest cover has more influence than the sandy soils; however there are high recharge rates in the loess regions since the predominant use as farmland is more important than the low permeability of the small loess particles.

Carbon sequestration: Although carbon is stored both in vegetation and soils, we consider the potential mineralisation of soil carbon only, which is high in semi-terrestrial and peat soils. Semi-terrestrial soils are typical for floodplains and are abundant in the Oberlausitzer Heide- und Teichgebiet. Such sites are rare or lacking in other physical regions of the study area. In addition, there are only few and small bogs in the north of the study area (especially in the Muskauer Heide and the Lausitzer Grenzwall) (Figs 2, 3). The majority of these sites are protected and not relevant for energy crop production. Hence, the mineralization of soil carbon has no essential effect within the study region.

Habitat function: The district of Görlitz is characterized by a large number of protected areas and high value assets, but also risks to biodiversity and habitat functions, especially in the biophysical units Zittauer Gebirge, Muskauer Heide, Lausitzer Grenzwall and Oberlau–sitzer Heide- und Teichgebiet; the latter contains the only biosphere reserve in Saxony.

Special conflicts can be expected where protected areas (e.g. Special Protection Areas for birds) are occupied by agriculture (farmland, grassland). Intensive agriculture, which is also pushed by energy crop cultivation, is one essential reason for the decline of bird populations, e.g. the partridge and the lapwing in recent years and decades (Dziewaty, Bernardy, 2007).

Landscape aesthetic value: Landscapes with above-average aesthetic qualities but also high vulnerability coincide with the large forests in the south (the Zittau Mountains) and the north (the Muskauer Heide and the Lausitzer Grenzwall), as well as several small forest areas which are also landscape protection areas, nature reserves and other protected areas in several parts of the district.

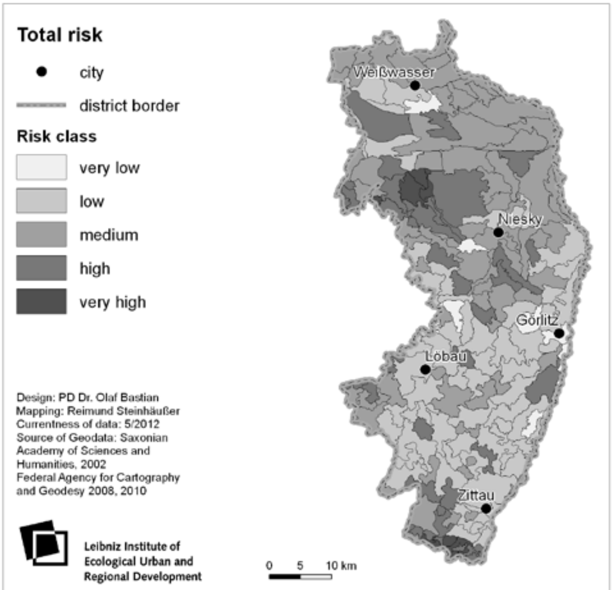

Fig. 4. Overall risk faced by a package of ecosystem services caused by increased energy crop cultivation, related to biophysical units (micro-chores) in the district of Görlitz.

Total risks

The overall risk faced by a package of several ES (see Sections 2 and 3) is shown in Fig. 4. The micro-chores in the western parts of the Oberlausitzer Heide- und Teichgebiet and the Muskauer Heide face high and very high risks, while those in the north half of the district and in the Oberlausitzer Bergland in the southwest face medium risks and those in the loess hilly regions of the central and eastern parts of the district generally face rather low risks.

Scenarios

The scenarios are connected with different changes in land cover and, to a greater degree, with changes in land use intensity. T a b l e 2 summarizes the general consequences for the ES (supply, risks) without considering the local specifics in terms of the sensitivity of particular micro-chores, or the effect of existing or planned biogas plants, which could promote the cultivation of energy crops. These modifications are considered in data tables (not published) and figures (e.g. Fig. 5). Some micro-chores in the north, and to a lesser degree in the east, represent a special case: large-scale lignite mining as well as the ensuing reclamation (flooding of the remaining opencast pits, reforestation of mining dumps) leads or has led to the total destruction of the original biophysical units, and has fundamental implications for ES.

T a b l e 2. Principal changes in risks for ES, according to three scenarios of energy crop cultivation.

ES	**Current trend scenario**		**Diversification scenario**		**Intensification scenario**	
	Tendency	Reason	Tendency	Reason	Tendency	Reason
Erosion	0	> maize, < humus, > forests and landscape elements		> woods in agricultural areas	0	> SRC, but partly more intensive agricultural use
Nitrate/pesticide leaching	0	see above	↓	see above	0	see above
Groundwater recharge	0	minimal land use changes	0	minimal land use changes	↑	only if > SRC, otherwise 0
Carbon sequestration	↑	> land use intensity	↓	see above	0	> SRC, but more intensive use of forests
Habitat function / biodiversity	↑	see above	* ↓	> woods, diversification	↑	> SRC and more intensive agriculture and forestry
Landscape aesthetic value	↑	see above	↓	> woods in the agricultural areas	↑	see above

Notes: SRC — Short rotation coppices; * — in forest areas 0, because of the in many cases more intensive forestry; 0 – constant – no or insignificant changes; ↑ — increases in risks; ↓ — decreases in risks.

The following section gives a more detailed explanation of selected scenario results in a note form which could be represented in Table 2 only in general.

Resistance to soil erosion

All scenarios: mainly un-wooded micro-chores: no significant change; open-cast mines: considerable increase in risk in newly developed mines, decrease through reclamation (reforestation);

Current trend scenario: no changes in strictly protected areas; higher risks on farmland near existing or planned biogas plants, due to higher shares of maize in the crop rotation;
Diversification scenario: constant in the neighbourhood of biogas plants; otherwise less erosion risks, thanks to more careful farming practices and higher shares of woods in the landscape;
Intensification scenario: strong decline of wind erosion risks by large-scale short rotation coppices on the poor sandy soils in the open landscapes of the Muskauer Heide and the Lausitzer Grenzwall; increase in other biophysical units (except large protected areas remote from biogas plants).

Resistance to nitrate leaching

Similar conditions as those for soil erosion.

Groundwater recharge

Current trend and diversification scenarios: non-wooded micro-chores: strong/ very strong decrease of the ES (and higher risks for it) in the northern parts through large scale short rotation coppices, no changes in other physical units or in protected areas;
All scenarios: wooded micro-chores: no change; open-cast mines: slight increase in risks in reclamation areas (reduced recharge after reforestation), initial mine developments involve much higher risks, due to lowering the groundwater table.

Carbon sequestration

Current trend scenario: no changes in protected areas, otherwise higher risks (lower sequestration) caused by increasing farming intensity;
Diversification scenario: forest areas: constant; non-wooded areas: increase of the ES due to more woods and careful treatment; vicinity of biogas plants: constant;
Intensification scenario: forest areas: decrease of the ES (and higher risks for it) due to more timber extraction (except in protected areas, particularly nature reserves); non-wooded areas: strong/very strong increase of the ES (and lower risks) in the Muskauer Heide and the Oberlausitzer Heide- und Teichgebiet due to high or very high amounts of short rotation coppices, otherwise decrease (of the ES) due to more intensive agriculture (except in nature reserves); open-cast mines: development of new mines: reduced sequestration due to the removal of the vegetation cover and upper soil layers, including bogs, moreover the huge amount of CO_2 which is released through burning the excavated coal; reclamation areas: higher levels of carbon sequestration after reforestation.

Habitat function

Current trend scenario: almost no significant changes in protected areas, but higher risks in the vicinity of biogas plants (if more maize is cultivated);

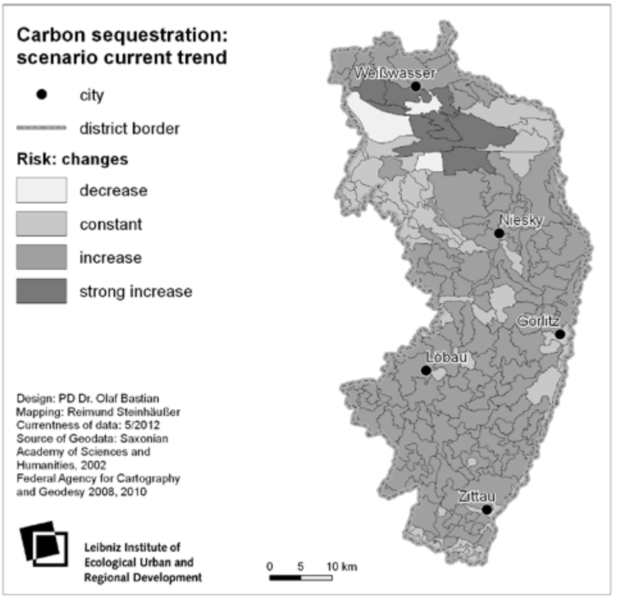

Fig. 5a. Changes in risks for carbon sequestration under three scenarios of energy crop cultivation in the biophysical units (micro-chores) of the Görlitz district.

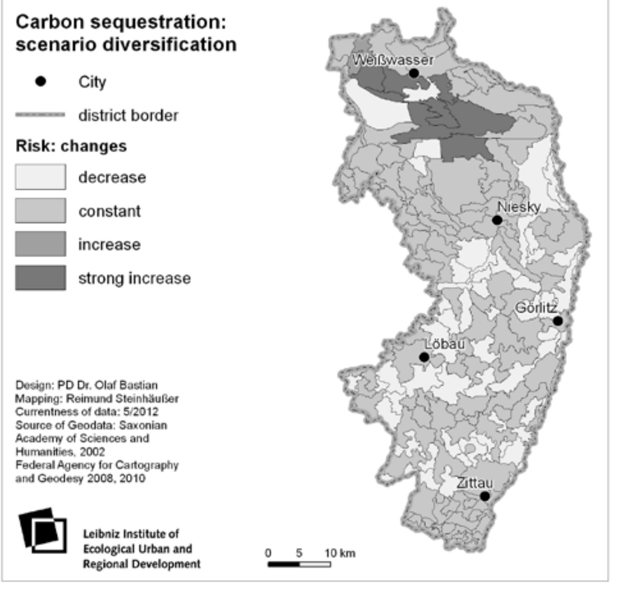

Fig. 5b. Changes in risks for carbon sequestration under three scenarios of energy crop cultivation in the biophysical units (micro-chores) of the Görlitz district.

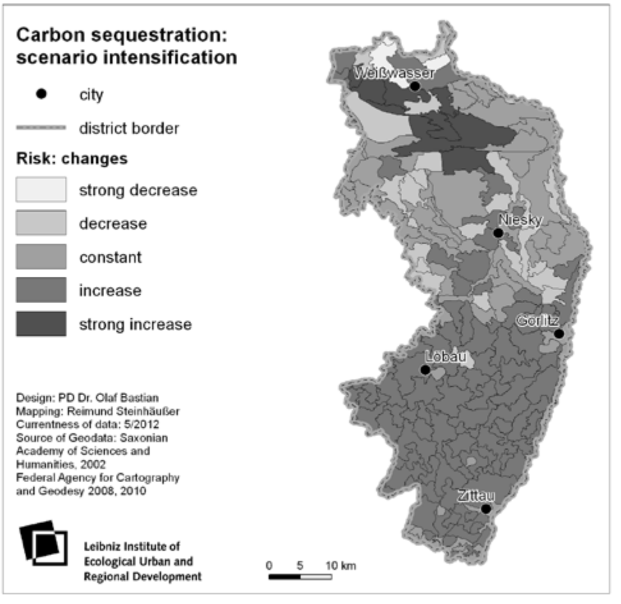

Fig. 5c. Changes in risks for carbon sequestration under three scenarios of energy crop cultivation in the biophysical units (micro-chores) of the Görlitz district.

Diversification scenario: forest areas: some decrease of the ES (and higher risks) caused by intensified use of timber, no changes in protected areas in forest and pond regions, improved situation in the agricultural landscape;
Intensification scenario: no changes in protected areas, decreasing biodiversity (higher risks) in open areas (farmland, grassland) of the Muskauer Heide, the Lausitzer Grenzwall and the Oberlausitzer Heide- und Teichgebiet, because the short rotation coppices would replace oligotrophic species and habitats; other forest and agricultural areas: biodiversity decline due to intensified land use, very strong decline (high risks) near biogas plants; open-cast mines: strong deterioration at newly developed mines, improved situation after conclusion coal mining, reclamation or succession.

Landscape aesthetic value

Current scenario: no changes in protected areas (particularly in landscape protection areas), otherwise reduced aesthetic values (= higher risks) due to monocultures and intensified use of forests;
Diversification scenario: no changes in protected areas and forests, otherwise improvements (except near biogas plants),
Intensification scenario: no changes in protected areas; in the Oberlausitzer Heide- und Teichgebiet and especially the Muskauer Heide and the Lausitzer Grenzwall higher risks due

to land use intensification or afforestation of open areas with short rotation coppices; other areas (non-wooded): higher risks; open-cast mines: improved situation in former mines due to reclamation (reforestation, formation of surface waters – lakes), sharp deterioration for new mine developments.

Integrated assessment (overall risks)

Current trend scenario: reduced risks only in old open-cast mining areas, due to reclamation; more or less constant in protected areas; increasing risks in open landscapes and somewhat in forests; strong increase in agricultural areas with biogas plants;
Diversification scenario: sometimes considerable reduction in risks in agricultural regions, particularly in the south, and in open-cast mines after reclamation; constant in protected areas and in agricultural areas with biogas plants;
Intensification scenario: major increase in risks in the agricultural landscapes of the south; higher risks in intensively used agricultural and forest areas; constant in strictly protected areas (biosphere reserve, nature park, some Natura 2000 sites);
All scenarios: active open-cast mines: major increase in risks.

Results of the surveys among inhabitants, key stakeholders and farmers of the Görlitz district

Key stakeholders perceived that biomass production is less important in Görlitz district than in other regions in Germany, especially compared with the situation in the western state of Lower Saxony. There would be potentials for an increased in biomass use for energetical purposes. Potentials were seen for woody biomass and non-edible energy plants, to avoid a "plate-or-tank" discussion. Also, transport should be restricted, to avoid negative carbon balances. Almost all stakeholders demanded more powerful regulatory tools, laws and incentives to achieve better spatial differentiation of biomass cultivation and avoid intensive cultivation of energy crops on sensitive sites, such as protected areas or slopes (to prevent erosion).

The semi-structured interviews among farmers revealed that the surveyed farmers value biomass production as one segment of their portfolios – as one pillar among others, or a second business mainstay with an additional source of income. Bio-energy from crops should be integrated into farm operations to allow for closed material cycles. Biomass transports should be restricted to short distances (below 10—20 km). Several farmers also emphasized a strong moral commitment to supply, and optimizing various ES for the benefit of society.

Initial results of the survey among residents of Görlitz district indicate that some provision of drinking water and biodiversity (referred to as "wild animals and plants" in the questionnaire) are perceived as the most important issues for this group; the provision of biomass for energy purposes is less important (Fig. 6). A vast majority wants to focus energy crop cultivation on sites not needed for food production. They welcome even an increased use of organic waste and landscape management materials, as opposed to energy crops per se, for biofuel use. A vast majority of interviewees also demands overall improvements in biodiversity and ES provision on agricultural land. While about one fourth of the persons states that possible extra costs and potential losses should be covered by farmers, a majority wants to spend more money to support such ES by shifting more tax money, mainly from the defence budget. A significant number of interviewees, however, expressed the willingness to pay an additional tax, or to donate voluntarily.

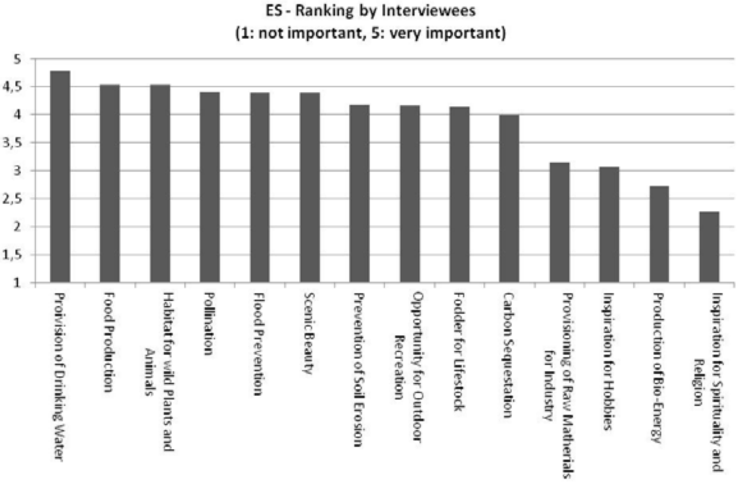

Fig. 6. One of the questions asked in standardized interview sheets for passers-by in Görlitz district: Which ES should be supplied by farmland?

Discussion and conclusion

For good reason, the ecosystem service concept has received much attention in the political sphere in recent years (MA, 2005; TEEB, 2010; CBD, 2010) as well as in the research community (e.g. Burkhard et al., 2012).

The application and assessment of ES is seen as an innovative step towards sustainable land use. The attractiveness of the ES concept results from its integrative and interdisciplinary character. It explicitly involves both natural and socio-economic science views and approaches (Müller, Burkhard, 2007), and addresses all pillars of sustainability. The ecosystem service (ES) concept can also fulfil the role of an eye-opening metaphor (Norgaard, 2010), as it stresses the high relevance of ecosystem structures and processes to human well-being.

By means of an assessment of ES, it is possible to reveal the impacts of energy crop cultivation and to objectify the discussions about renewable energies, so as to achieve long-term sustainable solutions.

Both the analyses of the status quo and the scenarios show that the increased production of bio-energy crops leads to higher land use intensities and to land use conflicts, and reduces the supply of several ES, such as regulation of soil erosion, carbon sequestration, habitat values and landscape aesthetic value.

It should be clear, however, that such threats are not completely new phenomena, but can be compared with problems caused by the intensification of agriculture or forestry for increasing food, feed or raw material production purposes.

We can state that the environmentally friendly image of "green energy sources" is partly based on misjudgements, and that "green energy" is not "green" and sustainable per se, but may cause serious environmental impacts, e.g. involving biodiversity or carbon sequestration. For example, only recently, the European Environmental Agency (2011) noted that "it is widely assumed that biomass combustion would be inherently 'carbon neutral', because it only releases carbon taken from the atmosphere during plant growth. However, this assumption is not correct and results in a form of double-counting, as it ignores the fact that using land to produce plants for energy typically means that this land is not producing plants for other purposes, including carbon otherwise sequestered. If bio-energy production replaces forests, reduces forest stocks or reduces forest growth, which would otherwise sequester more carbon, it can increase the atmospheric carbon concentration. If bio-energy crops displace food crops, this may lead to more hunger … and … to emissions from land-use change ..."

Due to differentiation of natural, geographical and spatial features, a research design using a case study on the landscape level is a very promising approach (Rode, Kanning, 2006). By the introduction of biophysical units (macro-chores, micro-chores), the spatial differentiation of ecological consequences of increased energy crop cultivation could be illustrated. The scenario analysis shows different possible future ways of development. They may be extreme, but they illustrate the range of possible change, and the resulting consequences.

The interviews showed that the various ES have quite different priorities among people and the main task of agriculture is not seen in the provision of biomass for energy purposes rather than for raising food. Also, regulatory (i.e., ecological) ES, such as the supply of clean drinking water (groundwater recharge) and biodiversity, are highly appreciated. Other surveys on nature awareness indicate a great demand for high environmental standards and an appreciation of the relevance of environmental protection among almost all groups of society (Lupp, Konold, 2008; Sinus Sociovision, 2009; BfN, 2009; UBA, 2009). The BfN study (BfN, 2009) also indicates a demand in many sectors of society for stricter laws and better protection of ES, as well as offset payments for the destruction of nature.

Sustainable land use schemes have to consider the present and possible future consequences of energy crop production, but also the preferences of the people in order to achieve really long-term sustainable solutions.

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