ESMERALDA

CASE STUDY BOOKLET

(Picture taken ca. 1990)

Mapping ecosystem services dynamics in an agricultural landscape in Germany

June 2018

ESMERALDA partner: Christian Albrechts University Kiel (CAU)

Case Study Coordinators: Benjamin Burkhard, Marion Kruse, Felix Müller

ESMERALDA

Enhancing ES mapping for policy and decision making

Suggested Citation: Burkhard, B., Kruse, M., Müller, F., Viinikka, A., Pitkanen, K., Adem Esmail, B., Geneletti, D., (2018). Case Study Booklet: MAPPING ES DYNAMICS IN AN AGRICULTURAL LANDSCAPE IN GERMANY prepared for "WS3 - Testing the methods across Europe" held in Prague, Czechia, 26-29 September 2016. ESMERALDA EC H2020 Grant Agreement no. 642007.

Table of Content

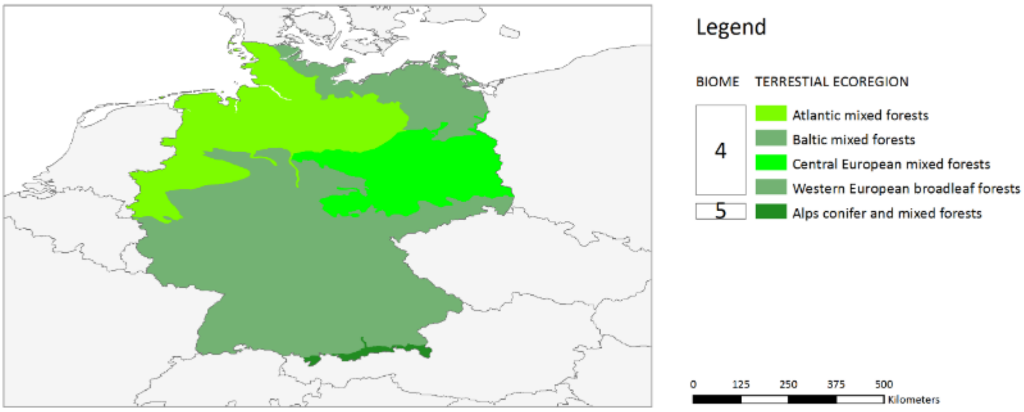
CASE STUDY FACTSHEET

Mapping ES dynamics in agricultural landscapes WS3_cs3

NAME AND LOCATION OF STUDY AREA	Bornhöved lakes district, Schleswig-Holstein
COUNTRY	Germany

STATUS OF MAES IMPLEMENTATION	Stage 1	Stage 2	**Stage 3**

BIOMES IN COUNTRY	1 Tropical & Subtropical Moist Broadleaf Forests	**4 Temperate Broadleaf & Mixed Forests**
	5 Temperate Conifer Forests	6 Boreal Forests/Taiga
	8 Temperate Grasslands, Savannas & Shrublands	11 Tundra
	12 Mediterranean Forests, Woodlands & Scrub	13 Deserts and Xeric Shrublands
	14 Mangrove	



case study outline

SCALE	national	sub-national	**Local**
AREAL EXTENSION	Ca. 60 km²		

THEMES	nature conservation	climate, water and energy	marine policy	natural risk
	urban and spatial planning	green infrastructures	agriculture and forestry	business, industry and tourism
	health	**ES mapping and assessment**		

ECOSYSTEM TYPES	urban	**cropland**	**Grassland**	**woodland and forest**
	heathland and shrub	sparsely vegetated land	Wetlands	**rivers and lakes**
	marine inlets and transitional waters	coastal	Shelf	open ocean

1. Overview of the study area

[*Copied & modified from Kandziora et al. 2014*[1]] The Bornhöved Lakes District (German Bornhöveder Seenkette) is located 30 km south of the federal state capital Kiel. The study area was delimited to a size of 60 km² and lies partly within ten municipalities in the two districts of Plön and Segeberg. Located on the outskirts of the Weichselian glaciation, the northern part of the Bornhöved Lakes Districts belongs to the moraine area of the “Ostholsteinisches Hügelland” with its diversified relief. The southern part, the so-called “Trappenkamper Sander” contains mostly fluvioglacial deposits. Six glacially formed lakes (between 0.27-1.4 km²) are predominate features, which are surrounded by forest areas. The lakes have been landscape protection areas since 1962 and partly conservation areas since 1983. Predominant soils are luvisols, cambic arenosols, and histosols. The Bornhöved Lakes District was the focus of an interdisciplinary ecosystem research project, which has been conducted from 1988 to 2001.

The area is an important supplier of multiple ES due to the large extent of agroecosystems (see land use map Figure 1.1 and Figure 4.1), forests and lakes and it is considered a representative landscape for Northern Germany. Furthermore, it is a good example for development of agricultural land use and related ES supply and demand over the past decades.

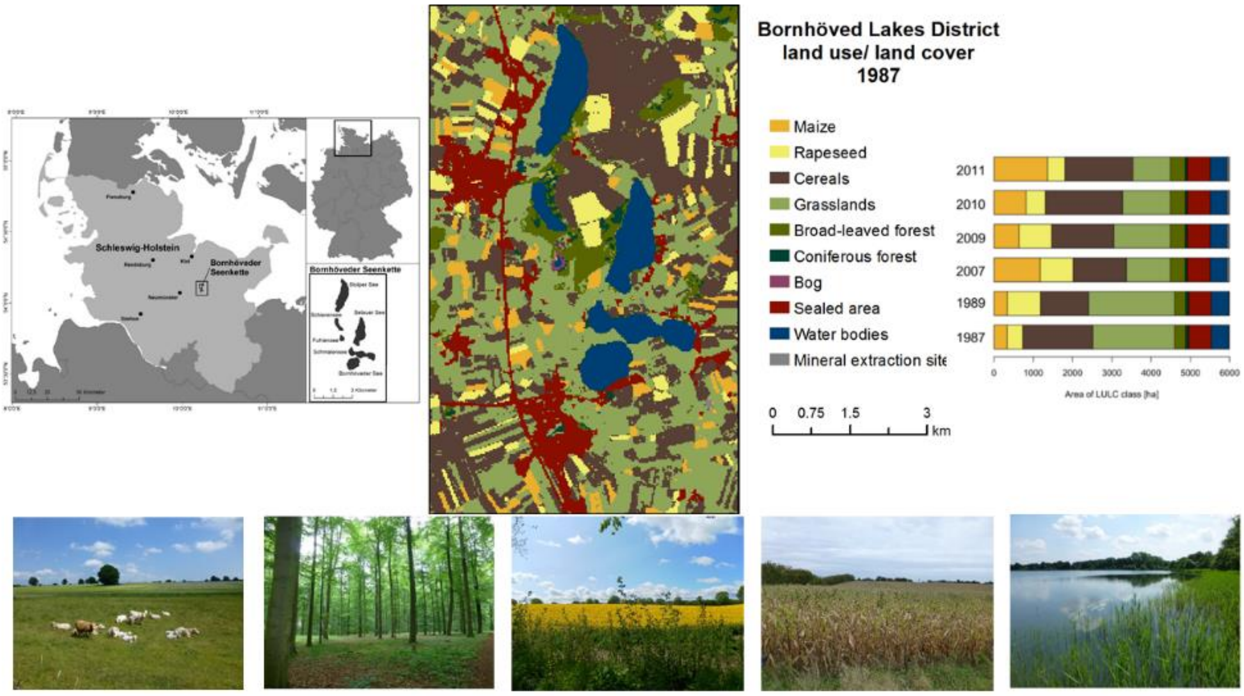


Figure 1.1. Location of the study area (top left; example land use/land cover map and their dynamics (top right); impressions from the area (bottom: All photos taken by Marion Kandziora Kruse).

[1] http://www.landscapeonline.de/wp-content/uploads/DOI103097-LO201435.pdf [Open Access]

2. Questions and Themes

ES mapping and assessment in the case study have been so far mainly scientifically driven. This means that the ES assessment framework (including indicators, quantification methods, etc.) was applied and tested in the area. The case study is partially part of the LTER (Long Term Ecological Research) program. Several ecological data sets are available from previous projects (e.g. Long-Term Research in the Bornhöved Lake District; see Fränzle et al. 2008[2]). This information is used to detect changes in ecosystem conditions, biodiversity, ecosystem functions, land use and other human activities in the area.

The land cover pattern in the area has been rather constant in the last decades. However, significant changes in agricultural land use regarding crop rotation are obvious. This is mostly due to policy changes in Germany that have been heavily promoting and supporting the use of renewable energy since the past years[3]. Resulting impacts were analyzed by land use change detection and statistical analyses of resulting changes in ES supply and demand. The increasing cultivation of energy plants (such as maize or rapeseed) for biomass generation has caused changes especially within provisioning ES (e.g. Figure 2.1). Their supply shows a shift from fodder (and partly food) production towards biomass for energy. The increasing cultivation of maize has further effects on biodiversity, regulating and cultural ES. Thus, the real-life policy question to be addressed would be:

"*How does the national German renewable energy strategy impact on the regional land use / land cover and related ES supply in a northern German agricultural landscape*?"

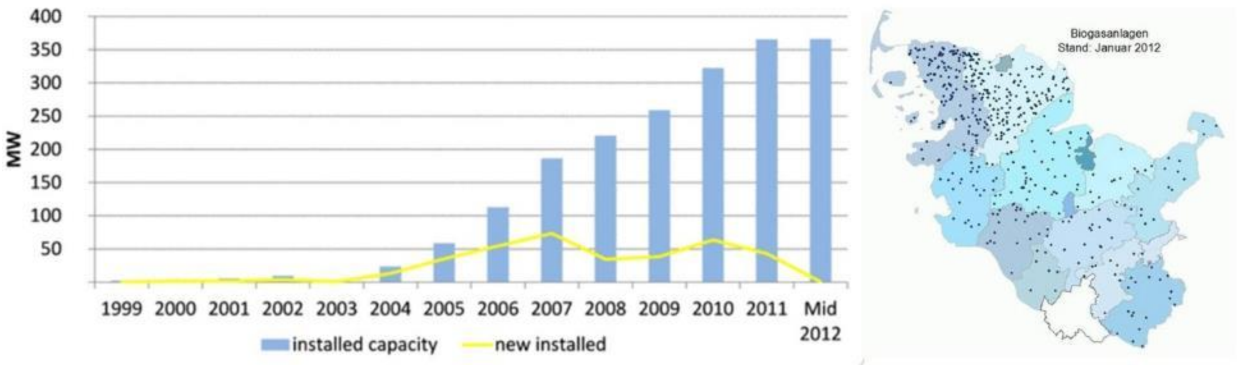


Figure 2.1. Development of electricity generation based on biomass (left) and map of biogas power plants (right) in the federal state of Schleswig-Holstein (Source[4]).

3. Stakeholders' involvement

Landowners/farmers were involved in the preceding project "Long-Term Research in the Bornhöved Lake District" (see Fränzle et al. 2008[5]) in order to carry out research on their property or to acquire information about their land use activities. However, in the actual ES mapping and assessment, stakeholders were mainly involved as experts for selected ES quantifications or for data requests (e.g., governmental departments).

[2] http://www.springer.com/de/book/9783540758105
[3] http://www.bmwi.de/EN/Topics/Energy/renewable-energy.html
[4] http://info.furgy.eu/en/energiethemen/bioenergie/bioenergy-in-schleswig-holstein
[5] http://www.springer.com/de/book/9783540758105

Landowners/farmers should be included further in order to analyses and to quantify in detail changes in agricultural activities and how policy is changing their behaviour (e.g. due to increasing cultivation of biomass for energy). Furthermore, local people and other land users should be included to quantify for example recreational activities and other cultural ES, besides the (supraregional) tourists (mainly day trips). The existing data and experience from prior ecosystem condition (ecological integrity) assessments could be used to identify linkages between ecosystem conditions and ES supply.

One key federal state-level stakeholder is the State Agency for Agriculture, the Environment and Rural Areas[6] of Schleswig-Holstein. Their tasks include state-level fishery, emission protection, water management, nature conservation, waste management and soils, all relevant for biodiversity and ES.

4. Initiating Mapping and Assessment

4.1. Identification and mapping of ecosystem type(s)

Corine land cover data (from 1990, 2000 and 2006) were the initial data source for a preliminary study. The maps were compared and changes detected. The main land cover type is agricultural areas and there were only little changes in the different land cover classes. One larger land cover change was the increase of open cast mining areas (sand and gravel extraction).

As the case study area is very relevant for supply of provisioning ES, the focus was brought to a more detailed analysis of crop cultivation and rotation changes. Other available official data sets such as ATKIS[7] (Authorative Topographic-Cartographic Information System) were applied as well. However, they also did not sufficiently reveal temporal (i.e. annual) land use changes in the agricultural classes. Therefore an own LANDSAT image-based land use / land cover classification was conducted. The resulting time series was the base for a change analysis with statistical data and gave the possibility to have more detailed spatially explicit data for mapping ES. The spatial resolution of LANDSAT data is 30 m x 30 m, the temporal resolution was based on yearly data sets from 2007 and 2009-2011 and the years 1987 and 1989 for comparison. Currently, the attempt is made to continue the analysis until 2015. The developed approach was aimed at being easy to reproduce and to upscale, for example for the whole federal state of Schleswig-Holstein, to be able to compare changes and impacts and to formulate guidelines for sustainable landscape management and policy-making.

[6] http://www.schleswig-holstein.de/DE/Landesregierung/LLUR/llur_node.html
[7] http://www.adv-online.de/Geotopography/ATKIS/

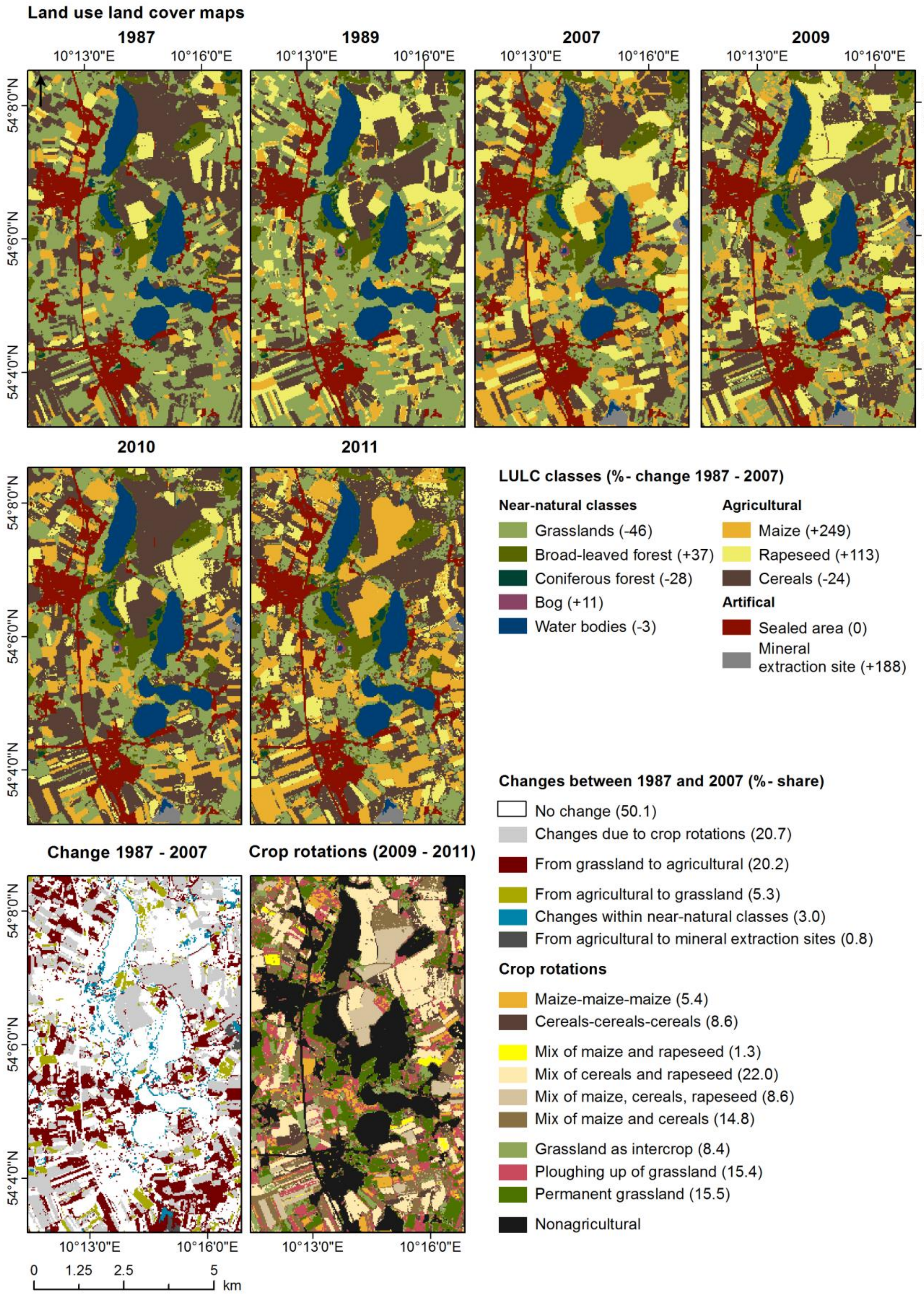


Figure 4.1. Land use / land cover maps for the Bornhöved Lakes District. Changes [%] in area between 1987 and 2007 are listed in parentheses (see legend) and illustrated spatially in the third row. The third row presents retrieved crop rotations from 2009 – 2011. Share [%] is shown in parentheses (see legend) [Kandziora et al. 2014].

4.2. Assessing ecosystem conditions

Ecosystem conditions have been assessed based on the concept of ecological integrity during the long-term ecosystem research project ''Bornhöved Lakes'', which has been conducted between 1988 and 2001. An ecological integrity indicator set has been applied within several case studies on different scales. The indicators related to landscape organization and energy, water and matter budgets that were quantified based on direct measurements, model outputs and other data sources. Within the main research area ''Altekoppel'', comparative empirical ecosystem studies were carried out in agroecosystems and forests with specific focus on a 100 years old beech forest and a directly neighbouring arable land ecosystem (see Figure 4.2). Both ecosystems had a similar agricultural use before the forest was planted.

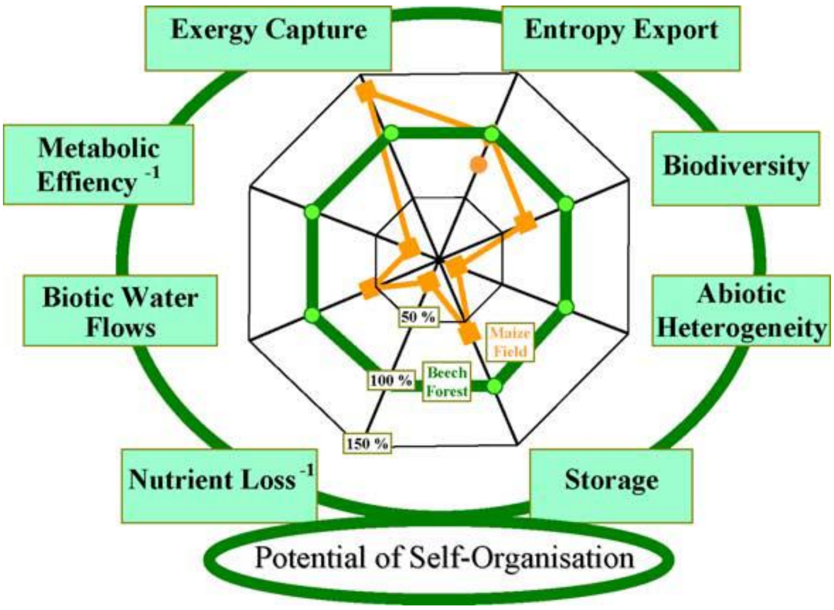


Figure 4.2. Synopsis of the ecological integrity indicator values for the two compared ecosystems (Source: Müller 2005[8]).

In a next step, the ecological integrity indicators were (hypothetically) related to the main categories of ES (see Table 4.1). These hypotheses and individual relations should be tested in further studies.

Table 4.1. Ecological integrity (ecosystem conditions) as basis for ES provision (Source: Müller & Burkhard 2007[9]).

		Ecosystem service			
		Supporting	Provisioning	Regulating	Cultural
Components of ecological integrity	Exergy capture	X	X	X	
	Exergy dissipation	X		X	
	Biotic water flows	X	X	X	
	Metabolic efficiency	X		X	
	Nutrient loss	X	X	X	
	Storage capacity	X	X	X	
	Biotic diversity	X	X	X	X
	Organization	X	X	X	X

[8] http://www.sciencedirect.com/science/article/pii/S1470160X05000257
[9] http://www.springer.com/us/book/9783540367628

4.3. Selecting Ecosystem Services

Relevant ES were identified based on: (a) identified land use / land cover changes and their effects of ES, and (b) data and respective quantification methods availability (also driven by the precedent long-term ecosystem research project). ES that were identified based on a) are especially suitable to address the policy question described in the first section, whereas the ecosystem research data (b) provide information about long-term dynamics of ecosystem conditions.

The identification and quantification of ES has been based on an own ("Kiel") classification system (published in the "ES matrix" in Burkhard et al. 2009 and updated by Kandziora et al. 2013). Table 4.2 shows the ES considered in the study according to the CICES classification. Besides the ES mentioned in Table 4.2, expert-based spreadsheet (method A1) ES supply (potential and flow) and demand scorings were carried out for 11 regulating, 14 provisioning and 5 cultural ES (Burkhard et al. 2014).

Table 4.2. Overview of the ES and related mapping and assessment methods in the German case study

ES selected for mapping and assessment	B	S	E
1.1.1.1 Cultivated crops	X		
1.1.1.2 Reared animals and their outputs	X		
1.2.1.2 Materials from plants, algae and animals for agricultural use	X		
1.3.1.1 Plant-based [energy] resources*	X		
2.2.1.1 Mass stabilization and control of erosion rates	X		
2.2.1.2 Buffering and attenuation of mass flows*	X		
2.3.1.1 Pollination and seed dispersal	X		
2.3.5.1 Global climate regulation by reduction of greenhouse gas concentrations	X		
3.1.2.2 Educational*		X	
3.1.2.5 Aesthetic		X	

* ES selected for further discussion during ESMERALDA workshops 3 in Prague
B = biophysical methods; S = socio-cultural methods; E = economic methods.

5. Methods for ES mapping and assessment

5.1. Biophysical methods for ES mapping and assessment

A broad range of biophysical data are available from the long-term ecological research that was carried out in the study area. They can be used to assess ecosystem condition; less for mapping due to their (for most indicators) lacking spatial extension. Newer studies focused on deriving data sets on land use/land cover changes (LULCC) based on satellite image interpretation, harnessing statistical data to quantify and map selected provisioning ES (Tier 2) and apply direct measurement and expert-based methods (Tier 1) and model outcomes (Tier 3) to quantify and map selected regulating ES.

5.1.1. Mapping of provisioning services

1.1.1.1 Cultivated crops
Indicator: *harvested crops (e.g. wheat yield* (dt/ha/a))
LULC was classified based on a Landsat TM 5 remote sensing data series covering the years 1987, 1989, 2007 and 2009-11. In combination with data from regional statistics (Tier 2) on crop supply and demand

(consumption), ES budgets for selected crops (cereals) were calculated and mapped for selected years (Resnikov 2016)[10]. Additional information can also be found in Kandziora et al. (2014)[11].

1.1.1.2 Reared animals and their outputs

Indicator: *number of livestock (only cattle) (n/a)*

Data from regional statistics (Tier 2) on the numbers of cattle in the case study area were used to quantify this ES in the years 1988, 2007 and 2010 (Kandziora at al. 2014)[7]. Changes of livestock numbers can be related to respective changes in grassland areas as supplier of fodder for livestock.

1.2.1.2 Materials from plants, algae and animals for agricultural use

Indicator: *harvested crops (e.g. wheat yield* (dt/ha/a))

LULCC was classified based on a Landsat TM 5 remote sensing data series covering the time period from 1987 to 2014. In combination with statistical data (Tier 2) on crop supply and demand, ES budgets for selected plants (maize, grass) for agricultural use (fodder for dairy cows) were calculated and mapped for selected years (Resnikov 2016)[6]. Additional information can also be found in Kandziora et al. (2014).

1.3.1.1 Plant-based [energy] resources

Indicator: *harvested crops (e.g. maize* (dt/ha/a))

LULCC was classified based on a Landsat TM 5 remote sensing data series covering the years 1987, 1989, 2007 and 2009-11. In combination with statistical data on crop supply and demand, ES budgets for selected plants (cereals, maize, and grass) for electricity generation in biogas plants were calculated and mapped for selected years (Resnikov 2016)[6]. Additional information in Kandziora et al. (2014)[7].

5.1.2. Mapping of regulating and maintenance services

2.2.1.1 Mass stabilization and control of erosion rates and

2.2.1.2 Buffering and attenuation of mass flows

Indicator: *Universal Soil Loss Equation*

This ES was quantified and mapped with the add-on water erosion tool in GISCAME. The aim was to analyse the effects of the change in crop rotation and share of grassland between 1987 and 2011 (loss of 50% grassland area).

2.3.1.1 Pollination and seed dispersal

Indicator: *Number of pollinators found in the traps*

Insect pollination of oilseed rape was quantified in the year 2015 based on direct measurement (Tier 1) of pollinator activities with pan traps and exclusion experiments along a gradient of landscape complexity

---

[10] Land Use Change Effects on Provisioning Ecosystem Services Supply and Demand - Case study Bornhöved Lakes District, Germany. MSc Thesis Sustainability, Society and the Environment. Kiel University.

[11] http://www.landscapeonline.de/wp-content/uploads/DOI103097-LO201435.pdf [Open Access]

in parts of the study area (Jähne 2016)[12]. In parallel, pollination has been modelled for the same area using InVest (Jähne 2016)[8].

2.3.5.1 Global climate regulation by reduction of greenhouse gas concentrations

Indicator: *carbon in different carbon pools (e.g. above-ground biomass, soils etc.)*
Global climate regulation was quantified and mapped based on the InVEST carbon model for the years 1987 and 2011 with primary and secondary data.

5.2. Socio-cultural methods for ES mapping and assessment

A broad set of ES supply and demand (11 regulating, 14 provisioning and 5 cultural ES) has been assessed based on the "ES matrix approach" using expert knowledge; see Burkhard et al. (2014)[13]. Two cultural ES have been assessed in another study (Mocior and Kruse 2016[14]) based on questionnaires.

5.2.1. Mapping of cultural services

3.1.2.2 Educational

Indicator: *survey data on qualitative scale*
In the frame of an exploratory survey with young experts (*n* = 37) from two universities, photographs from various landscapes (global distribution, with two examples from the Bornhöved case study) were evaluated on a relative scale for their educational value and criteria for the evaluation of the educational values were stated by the participants.

3.1.2.5 Aesthetic

Indicator: *survey data on qualitative scale*
A similar approach was conducted to analyze and discuss the aesthetic values of landscapes and the criteria involved since 6 years in one master's course at Kiel University.

5.3. Integration of ES mapping and assessment results

So far, the "ES matrix" was used to link geo-biophysical landscape units (e.g. land use types) to various ES by indicating supply capacities of/demands for various ES. The capacities have been assessed based on selected indicators and quantified using different approaches as previously described.

Future research will aim at integrating further quantification and mapping methods and data sources. Feedback from state-level authorities about the applicability of the mapping and assessment results will be used in order to figure out what kind of information, at which scale and accuracy level is actually needed for decision making on the one hand and what, on the other hand, science can provide considering available resources and justifiable efforts.

---

[12] Modelling and quantifying insect pollination of oilseed rape along a gradient of landscape complexity. MSc Thesis Sustainability, Society and the Environment. Kiel University 2016.
[13] http://www.landscapeonline.de/103097lo201434 [Open Access]
[14] http://www.sciencedirect.com/science/article/pii/S1470160X15003647

6. Dissemination and communication

So far, the outcomes have been published in scientific publications and one comprehensive book resulting from the long-term research project in the area. Future activities should work on the science-policy-society interface in order to make the results useful for decision making and (at least) to raise awareness about the importance of ecosystem conditions and services. Moreover, the methods that were developed and applied in the case study area are all transferable as they all are based on freely available data (such as Corine and LANDSAT) and methods.

7. References & Annexes

Reference

Burkhard, B., Kandziora, M., Hou, Y., Müller, F. (2014) Ecosystem Service Potentials, Flows and Demand – Concepts for Spatial Localisation, Indication and Quantification. Landscape Online 34: 1-32.

Fränzle, O., Kappen, L., Blume, H.-P., Dierßen, K. (Eds.) (2008) Ecosystem Organization of a Complex Landscape Long-Term Research in the Bornhöved Lake District, Germany. Ecological Studies. Springer.

Jähne, M. (2016) Modeling and quantifying insect pollination of oilseed rape along a gradient of landscape complexity. MSc Thesis Sustainability, Society and the Environment. Kiel University 2016.

Kandziora, M., Burkhard, B., Müller, F. (2013) Mapping provisioning ES at the local scale using data of varying spatial and temporal resolution. ES 4: 47-59.

Kandziora, M., Dörnhöfer, K., Oppelt, N., Müller, F. (2014) Detecting Land Use And Land Cover Changes in Northern German Agricultural Landscapes To Assess Ecosystem Service Dynamics. Landscape Online 35:1-24.

Mocior, E., Kruse, M. (2016) Educational values and services of ecosystems and landscapes – An overview. Ecological Indicators 60: 137–151.

Müller, F., Burkhard, B. (2007). An ecosystem based framework to link landscape structures, functions and services. In: Mander, Ü., Wiggering, H., Helming, K. (Eds.): Multifunctional Land Use – Meeting Future Demands for Landscape Goods and Services. Springer: 37-64.

Rensikov, N. (2016) Land Use Change Effects on Provisioning ES Supply and Demand - Case study Bornhöved Lakes District, Germany. MSc Thesis Sustainability, Society and the Environment. Kiel University.