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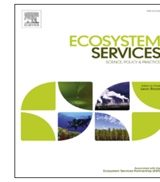

Mapping provisioning ecosystem services at the local scale using data of varying spatial and temporal resolution

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ABSTRACT

Spatial data on land use and land cover (LULC) are broadly available on different scales and are used widely for mapping ecosystem services as LULC and their changes impact on the provision of multiple ecosystem services. Here four spatial data sets were compared for their practicability as input data for the LULC based assessment method in the Bornhöved Lakes study area. The results for this 60 km² study area are that more detailed land use information (ATKIS and a combined ATKIS/InVeKoS/Landsat data set) is preferred to CORINE land cover data due to the possibility of including spatial details (e.g. number of LULC classes and crop information) in the assessment of provisioning ecosystem services. The CORINE data set overestimated the supply of the two analyzed provisioning services crops and fodder in comparison to the combined data set which revealed information on the specific crops, making quantification with statistical information on yields easier. Spatial input data quality has an effect on the resulting provisioning service maps and quantifications of ecosystem services in the study area due to the identification/omission of ecosystem services, their extent and change. Consequently they also influence decision-making and the development of the ecosystem services concept in the future.

1. Introduction

Mapping of ecosystem services is an arising and significant topic in the scientific community, which is evident in the amount of publications and special issues on the topic in recent time (Crossman et al., 2012). Burkhard et al. (2012a, p.2) define ecosystem services as "the contributions of ecosystem structure and function—in combination with other inputs—to human well-being". This definition includes the highly managed and human-influenced agroecosystems, which are extensively spread globally and provide bundles of ecosystem services (Raudsepp-Hearne et al., 2010) or "agrosystem services" (Papendiek et al., 2012). Maximizing only selected ecosystem services (e.g. agricultural production) causes effects and trade-offs concerning other ecosystem services, ecosystem functions and human well-being (Tallis and Polasky, 2009). Since the concept of ecosystem services has the potential to be brought widely into decision-making and planning (de Groot et al., 2010), the use of maps to visualize ecosystem services and their spatio-temporal distribution in local (Troy and Wilson, 2006), regional (Cheng et al., 2006; Koschke et al., 2012; Kroll et al., 2012; Vihervaara et al., 2010), national (Egoh et al., 2008), continental (Haines-Young et al., 2012; Maes et al., 2011) and global case studies (Costanza et al., 1997) are recognized as a key element. Being spatially explicit is a focal requirement for ecosystem service maps and models which is commonly considered to be of great importance (e.g. Nelson et al., 2009; Tallis and Polasky, 2009; Troy and Wilson, 2006). As a map can only communicate a limited amount of information, most mapping studies focus on selected ecosystem services (e.g. Cheng et al., 2006; Egoh et al., 2008; Eigenbrod et al., 2010; Gulickx et al., 2013; Kroll et al., 2012; Naidoo et al., 2008; Nedkov and Burkhard, 2012; Schulp et al., 2012; Turner et al., 2007; van Oudenhoven et al., 2012). These maps are a prerequisite for ecosystem or urban planning, management and the sustainable use of resources and ecosystem services (Burkhard et al., 2009; Caspersen and Olafsson, 2010; Cheng et al., 2006; Koschke et al., 2012; Schulp and Alkemade, 2011; Tallis and Polasky, 2009) and they also explicitly link ecosystem conservation to human well-being (Fisher et al., 2009; Krishnaswamy et al., 2009).

There are several approaches and methods to quantify, map and evaluate ecosystem services as the following short review reveals. Fagerholm and Käyhkö (2009) give the example of participatory mapping of ecosystem/landscape service indicators in rural environments for a bottom-up management. Social and community values were mapped by Bryan et al. (2010) and Raymond et al. (2009) in the Murray–Darling basin as a counterpart to economic and biophysical mapping. A GIS-based mapping approach for social values of ecosystem services was compiled by

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Sherrouse et al. (2011). For management and policy decisions, ecosystem service distributions and capacities also need to be assessed in scenario comparisons (Nelson et al., 2009; Troy and Wilson, 2006) or comparison of historic land use changes (Lautenbach et al., 2011) and trade-offs (Haines-Young et al., 2012). Metzger et al. (2008) quantify and map spatial vulnerability of ecosystem services in Europe linked to global change. Models like InVEST (Tallis and Polasky, 2009) claim to incorporate both supply and demand, which can differ greatly depending on the case study areas (Burkhard et al., 2012b). There are several other models available for mapping ecosystem service distribution, illustrating an increase in model-based mapping methods (Haines-Young et al., 2012). However, Schulp et al., (2012) state that until recently, there have been no studies which apply the whole function-services framework in the required spatially explicit manner.

Many mapping examples are carried out for economic valuation of ecosystem services based on value-transfer (Cheng et al., 2006; Costanza et al., 1997; Troy and Wilson, 2006). Eigenbrod et al. (2010) discuss the problems resulting from value or benefit transfer methods by extrapolating data to different scales. When modeling and mapping ecosystem services, the input data and spatio-temporal scales of ecosystem service supply should be in comparable scales and resolutions (Burkhard et al., 2012b; Schulp and Alkemade, 2011; Tallis and Polasky, 2009). Konarska et al. (2002) compare two spatial scales (1 km and 30 m resolution of remote sensing data) for economic valuation of ecosystem services for each US state, concluding that there is an increase of ecosystem service values based on the finer resolution data. Wegehenkel et al. (2006) point out the influence of spatial distribution and extent of LULC classes on hydrological model parameters such as runoff and ground water recharge, which are regulating ecosystem services.

Temporal resolution is often low compared to spatial resolution, limiting data sets to 1–2 years. For Europe, the CORINE data sets exist for three time steps until now (1990, 2000 and 2006). Global and continental land cover data sets are derived from remote sensing data, which has been shown by Krishnaswamy et al. (2009) as an appropriate method for e.g. large-area mapping of hydrological and carbon services in combination with habitat and forest variability and biodiversity. However, some ecosystem services act on a rather local scale, with annual variations, for example due to crop rotation in agricultural areas, which need to be explored in more detail.

Though there are a number of approaches, case studies and results, there are still several unanswered questions about the technique of mapping ecosystem services, like data availability as a limiting factor (Troy and Wilson, 2006) combined with limits in user rights of spatial data and methodological uncertainties (Crossman et al., in press).

Here, an assessment method is applied in a case study area in Northern Germany in light of the on-going development of the land cover-based assessment method introduced by Burkhard et al. (2009, 2012b), where CORINE land cover classes were assessed for their capacity to provide ecosystem services. Based on these publications, the following research questions will be discussed:

(i) Are CORINE land cover data suitable as land cover input data for a local scale ecosystem services assessment case study?
(ii) What are the advantages and limitations of other available official land use/land cover data sets for assessing ecosystem services on the local scale?
(iii) For the quantification of ecosystem services, the question is if the available official statistics give enough information to quantify ecosystem services in a sufficient amount for mapping provisioning services in this local case study.

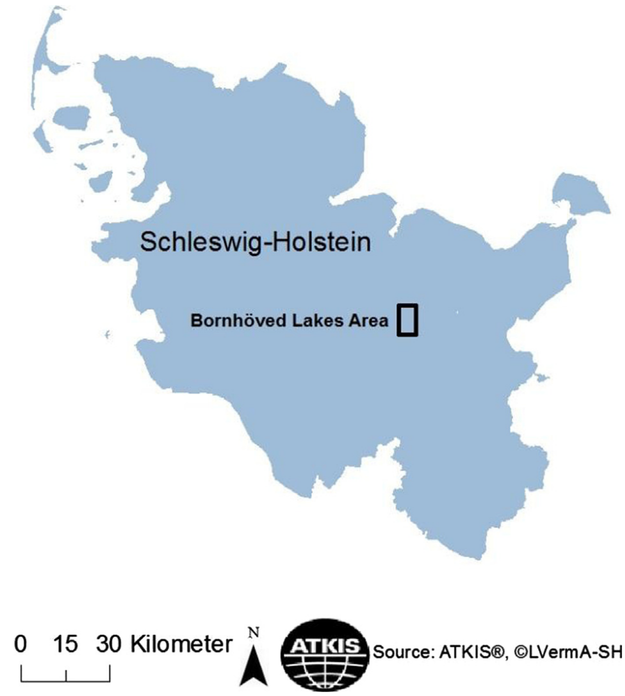

Fig. 1. Study area location in Schleswig-Holstein, Northern Germany.

First, four spatial datasets are introduced: CORINE, ATKIS, InVeKoS and a Landsat classification data set. These data sets are partly aggregated to three, which are used to generate LULC maps and their information content is compared. Then two provisioning services are quantified and mapped for the years 1990, 2000, 2006 (CORINE) and 2010 (ATKIS and the combined data set ATKIS/InVeKoS/Landsat). Based on the quantification and the resulting ecosystem services maps, the advantages and disadvantages of the data sets and LULC-based maps, together with further questions on mapping ecosystem services, are discussed.

2. Materials and methods

2.1. Study area and selection of provisioning ecosystem services

The study area is the Bornhöved Lakes Area, located in Northern Germany in the state of Schleswig-Holstein, approximately 30 km southwest of Kiel (Fig. 1). This study area was the focus of a 12-year integrative ecological study project (Fränzle et al., 2008) and is today part of the LTER network (LTER: Long-term ecological research; Müller et al., 2010).

Six glacially formed lakes (surface area ranging between 1.13 and 0.27 km²) and agroecosystems are the dominating landscape features. Forested areas, primarily around the lakes, and small settlements, which are larger in the west, are part of the study area as well (Fränzle et al., 2008; see Figs. 2–4).

For this analysis, the borders of the study area are defined by official topographic map sheets (German DGK scale 1:5000) resulting in a case study area of 60 km². The northern part of the case study area belongs to the administrative district of Plön, whereas the southern area is part of the district Segeberg.

As large parts of the case study area are used for agricultural production, the focus of this study is on provisioning ecosystem services. In this case, the provisioning ecosystem services were subdivided into "crops" for human nutrition and "fodder" for livestock breeding. Table 1 gives short definitions and potential indicators for the quantification of the two provisioning services.