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Evaluation of the accuracy of land-use based ecosystem service assessments for different thematic resolutions

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ABSTRACT

The demand for pragmatic tools for mapping ecosystem services (ES) has led to the widespread application of land-use based proxy methods, mostly using coarse thematic resolution classification systems. Although various studies have demonstrated the limited reliability of land use as an indicator of service delivery, this does not prevent the method from being frequently applied on different institutional levels. It has recently been argued that a more detailed land use classification system may increase the accuracy of this approach. This research statistically compares maps of predicted ES delivery based on land use scoring for three different thematic resolutions (number of classes) with maps of ES delivery produced by biophysical models. Our results demonstrate that using a more detailed land use classification system does not significantly increase the accuracy of land-use based ES assessments for the majority of the considered ES. Correlations between land-use based assessments and biophysical model outcomes are relatively strong for provisioning services, independent of the classification system. However, large discrepancies occur frequently between the score and the model-based estimate. We conclude that land use, as a simple indicator, is not effective enough to be used in environmental management as it cannot capture differences in abiotic conditions and ecological processes that explain differences in service delivery. Using land use as a simple indicator will therefore result in inappropriate management decisions, even if a highly detailed land use classification system is used.

1. Introduction

With the concept of ES finding its way into impact assessments, spatial planning and national nature and environment monitoring (de Groot et al., 2010; Landsberg et al., 2011; Maes et al., 2011), the need for straightforward assessment tools is clear (Kienast et al., 2009; Van der Biest et al., 2014). These tools should allow for consistent ES evaluation through time and across different levels of practice. The demand for such methods has stimulated the emergence of land-use based proxy methods for assessing the capacity of a landscape to deliver services, mostly using coarse thematic resolution classification systems (Burkhard et al., 2009, 2012). While these methods are powerful awareness-raising instruments, applying them on the level of decision-making may have adverse effects.

Despite the many studies showing the errors caused by using simplified proxies for ES delivery (Kienast et al., 2009; Eigenbrod et al., 2010; Lautenbach et al., 2011; Geijzendorffer and Roche, 2013; Hou et al., 2013), land use is still frequently applied as an indicator of service delivery (Maes et al., 2011, 2012; Nedkov and Burkhard, 2012; Schneiders et al., 2012). Although proxy-based methodologies are generally developed to be used on large spatial scales (Naidoo et al., 2008; Haines-Young et al., 2012; Maes et al., 2012), for awareness raising or as a starting point for more thorough assessments (Burkhard et al., 2012; Vihervaara et al., 2012), there is a danger that their easy application leads to the concepts being used outside of these contexts (Landsberg et al., 2011).

It has recently been argued that a more detailed land use classification system may increase the accuracy of land-use based ES assessments (Vihervaara et al., 2010; Burkhard et al., 2012; Vihervaara et al., 2012). Explanations for this are that coarse thematic resolution classification systems may not identify small,

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region-specific habitats that are of particular importance for the delivery of certain ES (Vihervaara et al., 2010; Schulp and Alkemade, 2011). Other arguments are the limited delineation of too-general classes (Vihervaara et al., 2010). Schulp and Alkemade (2011) argue that taking information on the spatial organization of the landscape into account would increase the accuracy of ES assessments. They also suggest including information on land cover as well as land use in the classification system.

In this study, we investigate the accuracy of existing land use classification systems for predicting ES delivery by comparing the results of a land-use based scoring method with the results of quantitative biophysical models. We then verify whether or not a finer thematic resolution and delineation of land use categories for the purpose of ES research improves the precision of land-use based ES assessments. Lastly, we analyze the extent to which land use can be used to make predictions on ES delivery and whether differences exist between the predictive capacity for provisioning and regulating services.

2. Materials and methodology

2.1. Study area

The analysis was carried out in the Central Campine ecoregion, an area of ~1100 km^2 located in North East Belgium (Fig. 1). The area is a typical low-relief lowland (about 30 m maximum elevation gain). Its soils mainly consist of sand and loamy sand, with loamy and boggy soils on alluvial plains and coarse sand on a series of inland dunes. The high population density (470 inhabitants/km^2) and historic land use make it a highly fragmented landscape (Antrop, 2004) with a median parcel size of less than 0.1 ha (residential property included). The western part of the study area covers the densely-populated suburban area around the city of Antwerp. In the East, buildings are scattered and follow typical ribbon development patterns, connecting villages throughout a landscape that is dominated by agriculture and forestry. Several small nature reserves are found within the study area.

2.2. Land use classification systems

The strength of correlation between land-use based qualitative scoring and process-based quantitative modeling of ES is analyzed for three land use classification systems with different thematic resolutions and mapping targets. These three land use classification systems differ in two crucial aspects, i.e. number of classes (thematic resolution) and purpose of classification.

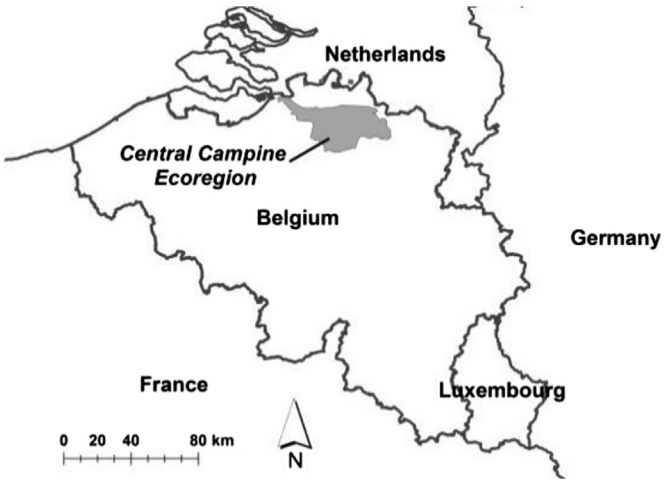

Fig. 1. Map of Belgium indicating the study area (Sevenant et al., 2002).

The **CORINE classification system** (Coordination of Information on the Environment, EEA, 2007) was selected because of its frequent use in ES assessments (Burkhard et al., 2009; Vihervaara et al., 2010; Maes et al., 2011; Burkhard et al., 2012; Maes et al., 2012; Zulian et al., 2014). It was originally developed in 1994 to represent the different European ecosystems and to enable European-level cross-border investigation and comparison (EEA, 1999). This study used the 2000 update of the classification system (CLC2000). Table 1 gives an overview of the original number of classes per main land use category for the corresponding version of the 2007 raster map (CLC2000 100 m × 100 m – version 9/2007).

The system developed by Gobin et al. (2009), hereafter referred to as the **governmental classification system**, was selected because of its frequent use in policy development in the Flemish region (Gobin et al., 2009; Schneiders et al., 2012; Broekx et al. 2013; Staes et al., 2014). The main way it differs from CORINE is in its combination of land cover information with management-related aspects (e.g. environmental targets, multifunctional targets, agricultural management, biodiversity management). The number of classes per main land use category distinguished on the original map (100 m × 100 m) of the study area is summarized in Table 1.

A third classification system was developed for the purposes of this study, specifically for ES mapping. It is hereafter referred to as the **Ecosystem Services Land Use Classification (ESLUC)**. It aims to provide a high level of detail, which is expected to allow for more accurate estimates of ES. A small group of experts (5) involved in ES research were asked to identify all the land cover classes they believed to differ at the level of service delivery. Since the majority of ES are controlled not only by land use or vegetation type but also by the abiotic environment, socio-economic factors and spatial relationships (Lautenbach et al., 2011; Nedkov and Burkhard, 2012; Hou et al., 2013), an 'ideal' land use classification system for ES should include distinctive categories reflecting the differences between these elements. The level of detail of the classification system, however, had to be adapted so that the system could be used on different institutional levels (Kienast et al., 2009; Hou et al., 2013). A classification system with a very high level of detail is impractical and may lead to erroneous interpretations when the classification system is used by people other than its developers.

A raster map with a resolution of 5 m × 5 m was created for the study area, using the ESLUC system. The map was constructed using the best and most detailed geographical data available, covering the entire study area and allowing for mapping of the ESLUC classes. The following data sources were used to create the map: the biological valuation map of Flanders (INBO, 2010) providing highly detailed information on vegetation type, the National Geographical Institute topographic vector database (NGI, 2007), the areas under nature management map (INBO, 2008), the intertidal flats map (INBO, 2007), the green map of Flanders (ANB, 2012), that distinguishes between high (>3 m) and low (<3 m) vegetation, and the agricultural land use map of Flanders (VLM, 2011). Table 1 gives an

Table 1
Number of classes occurring within the study area per main land use category for the three different original land use maps.

Land use map	Number of classes					
	Urban	Agricultural	Forest & semi-natural	Wetland	Water body	Total
CORINE	9	5	5	1	2	22
Governmental	16	7	5	2	1	32
ESLUC	18	11	23	8	5	65