Ecological Indicators 70 (2016) 382–392

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Integrating the spatial proximity effect into the assessment of changes in ecosystem services for biodiversity conservation

Yanfang Liu[a,b], Lei Zhang[a,*], Xiaojian Wei[c,d], Peng Xie[a]

[a] School of Resource and Environment Sciences, Wuhan University, 129 Luoyu Road, Wuhan 430079, China
[b] Collaborative Innovation Center of Geospatial information technology, Wuhan University, 129 Luoyu Road, Wuhan 430079, China
[c] Key Laboratory of Watershed Ecology and Geographical Environment Monitoring, National Administration of Surveying, Mapping and Geoinformation, China
[d] School of Geomatics, East China University of Technology, 418 Guanglan Road, Nanchang 330013, China

ARTICLE INFO

Article history:
Received 8 September 2015
Received in revised form 9 June 2016
Accepted 13 June 2016

Keywords:
Land cover change
Proximity effect
Ecosystem service
Biodiversity conservation
Land use planning

ABSTRACT

The assessment of the value of ecosystem services is a valuable tool for biodiversity conservation that can facilitate better environmental policy decision-making and land management, and can help land managers develop interventions to compensate for biodiversity loss at the patch level. Previous studies have suggested that it is appropriate to assess the value of biodiversity for conservation planning by considering both the condition of the landscape and the spatial configuration of adjacent land uses that can be reflected as a proximity effect. This research examines the influence of spatial proximity on biodiversity conservation from the ecosystem service perspective based on the assumption that the variation in the proximity effect caused by land cover change has positive or negative impacts on ecological services. Three factors related to the spatial characteristics of the landscape were considered in this approach: the relative artificiality of the land cover types, the distance decay effect of patches and the impact of one land cover type on others. The proximity effect change (PE_C) parameter reflected the relationship between the spatial proximity effect and biodiversity conservation. The results of a quantitative and spatial comparative analysis of the proposed method and the conventional method in Yingkou for the periods of 2000–2005 and 2005–2010 showed that the former can account for the temporal and spatial changes in ecosystem services for biodiversity conservation that were caused by patch-level changes as well as the interaction between the altered and adjacent patches from a spatial perspective. The metric can also identify the most critical areas for biodiversity protection and inform the efficient allocation of limited land resources for nature conservation to maximize the benefit to biodiversity by guiding the process of land-use change, particularly urbanization and agriculture. Future studies should focus on the other important factors that are applicable to the assessment of the value of biodiversity conservation in socio-ecological systems, where society and nature are mutually capable of fulfilling their roles.

1. Introduction

Ecosystem services have been defined as the benefits that people obtain, either directly or indirectly, from various ecosystems (Costanza et al., 1997; MEA, 2005a,b), and they are provided at various spatial and temporal scales (Hein et al., 2006), which are generally accepted to be structurally and functionally complex, spatially variable, and temporally dynamic (Wu, 2013). Land use change can have beneficial or detrimental effects on ecosystem services (Li et al., 2014), especially urban expansion (Su et al., 2014; Qiu et al., 2015) and agriculture (Li et al., 2014). Over the last decade, regional ecological services have been significantly degraded (Collin and Melloul, 2001; Lautenbach et al., 2011), and biodiversity, in particular, has deteriorated (Foley et al., 2005). To reverse this situation, numerous studies have considered the interactions between ecosystems and land use (Kreuter et al., 2001; Li et al., 2010a; Camacho-Valdez et al., 2014), and the assessment of ecosystem service value for conservation is regarded as a valuable tool to facilitate better environmental policy decision-making and environmental management (MEA, 2005a; Pejchar and Mooney, 2009; Camacho-Valdez et al., 2014; Wang et al., 2015).

Biodiversity has many definitions and multiple measures. It can be defined as "the diversity of life on Earth" (MEA, 2005b), and it is always regarded as "a regulator of underpinning ecosystem

* Corresponding author.
E-mail addresses: lzhang520@163.com, 330717373@qq.com (L. Zhang).

http://dx.doi.org/10.1016/j.ecolind.2016.06.019
1470-160X/

processes, as a final ecosystem service and as a good" (Mace et al., 2012). At the patch level, biodiversity is significantly influenced by land use, such as agricultural development (Swift et al., 2004). It is related to four factors that influence habitat quality: the relative impact of each threat, the relative sensitivity of each habitat to each threat, the distance between the sources of threats and the habitats, and the degree to which the land use is legally protected (Tallis et al., 2011), and threats are sometimes human-dominated landscapes, such as cropland and urban areas (Bai et al., 2011). In this study, biodiversity is regarded as an ecosystem service as defined by Costanza et al. (1997) and Xie et al. (2003).

Many methods have been proposed to assess the value of ecosystem services (Costanza et al., 1997; Eigenbrod et al., 2010; Syrbe and Walz, 2012; Ng et al., 2013), and they are divided into two categories: primary data-based and biome- or LULC proxy-based (Su et al., 2014). The value of the ecosystem services delivered by each land cover category has been widely assessed (Costanza et al., 1997; Xie et al., 2003; Ng et al., 2013), but estimations that are based solely on the condition of the landscape may be inappropriate for conservation planning without considering spatial configuration, habitat quality, landscape structure or adjacent land uses (Tallis and Polasky, 2009; Frank et al., 2012; Baral et al., 2013; Baral et al., 2014). However, the spatial aspects of landscape heterogeneity and configuration play a significant role in the maintenance biodiversity (Syrbe and Walz, 2012) because the capacity for providing goods and services within an ecosystem is not homogeneous across landscapes, and ecosystem services are not static phenomena (Fisher et al., 2009; Ng et al., 2013). To adequately evaluate changes in biodiversity caused by land use change from an ecosystem service perspective, knowledge of both the spatial characteristics of the landscape and habitat condition is required as well as the relationship with the surrounding landscape (Baral et al., 2014).

Landscape spatial characteristics are complicated and related to other ecologically significant variables that can result in undervaluing or overvaluing ecosystem services (Ng et al., 2013). Several studies have attempted to take landscape spatial characteristics into account when valuing ecosystem services for biodiversity conservation, such as landscape connectivity (Ng et al., 2013) and landscape structure (Frank et al., 2012). The proximity index, as one of the landscape spatial characteristics important to ecological conservation, defines the spatial context of a patch in relation to neighboring patches of the same type (Gustafson and Parker, 1992). The area and nearest-neighbor distance of a patch and its neighboring patches are always considered in the assessment (Gustafson and Parker, 1992). Many studies have considered proximity in the assessment of ecosystem service value (Tran et al., 2010), habitat quality related to biodiversity (Frank et al., 2012), habitat isolation (Su et al., 2010; Ng et al., 2011; Xun et al., 2014) and species richness (Houlahan and Findlay, 2003). Proximity effects caused by changes in land use, especially due to urban sprawl (Su et al., 2010), have been shown to influence ecological processes and the dynamics of local plant and animal populations or landscape qualities. Therefore, proximity should be considered to properly account for the spatial variability in ecosystem service values for biodiversity conservation caused by landscape configuration dynamics.

Our study was organized around two main research questions: (1) How does a change in the proximity effect influence ecosystem services for biodiversity conservation, and what land use changes cause such a proximity effect? (2) How do the spatio-temporal changes in patches affect biodiversity conservation, and how can biodiversity be maintained in land-use planning? To accomplish the proposed objective, Yingkou, which has undergone significant habitat loss and land cover change due to rapid urbanization during the periods of 2000–2005 and 2005–2010, was selected as a case study. A metric, the proximity effect change (PE_C) of patches, was calculated and analyzed to explain the relationship between the

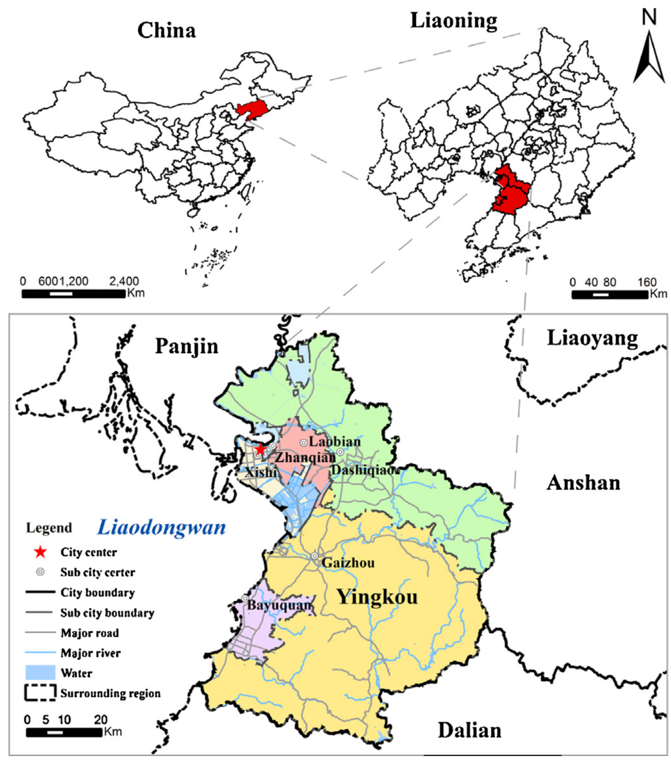

Fig. 1. Location of the study area.

proximity effect and biodiversity conservation. A comparative analysis of ecosystem services using the proposed method ($ESV\_B_{p\_c}$), with considers the influence of the proximity effect, and the conventional method (ESV_B_c) was conducted to analyze temporal and spatial changes in biodiversity conservation. The proposed method can identify that changes in biodiversity are not only caused by changes in patch size, but they also result from the influence of the proximity effect considering some related factors, such as the relative artificiality of land cover types, the distance decay effect of patches, and the impact of one land cover type on others. The method can also identify key areas for conservation and efficiently allocate land for nature conservation to maximize the benefits to biodiversity.

2. Materials and methods

2.1. Study area

The study was conducted in Yingkou City, which is located in the northwestern part of the Liaodong Peninsula in China (Fig. 1), and the entire area covers 527,900 ha and extends from $39^{\circ}55'$–$40^{\circ}56'$ N and $121^{\circ}56'$–$123^{\circ}02'$ E. This region is mountainous, and its eastern section is near Liaodongwan. Over the past 10 years, the area has experienced remarkably rapid economic growth and urbanization, with a population of 2.35 million and a gross domestic product of 100.24 billion yuan in 2010 (LPPG, 2011). In 2000–2010, the amount of urban area increased from 12.47% to 15.04% of the study area, and cropland decreased from 32.54% to 31.16% (Table 4). These land cover changes have significantly impacted ecosystem processes.

2.2. Data sources and preparation

Land cover types were derived from Landsat Thematic Mapper imagery taken in 2000, 2005, and 2010 (resolution: $30\,m \times 30\,m$). First, an atmospheric correction was performed with ENVI5.1, and a topographic correction based on a topographic map was then