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Land-use/land-cover change and ecosystem service provision in China

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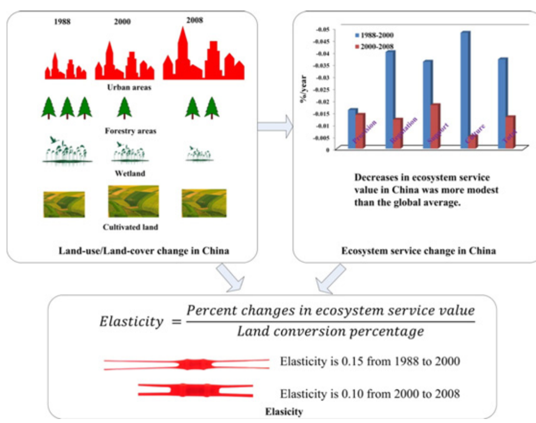
HIGHLIGHTS

- We examined the land-use/land-cover changes (LUCCs) in China from 2000 to 2008.
- We assessed the responses of ecosystem service values (ESVs) to LUCC in China.
- ESVs decreased by 0.45% and 0.10% during 1988–2000 and 2000–2008, respectively.
- Converting 1% of land led to ESV changes of 0.15% and 0.10% in these two periods.
- Decreases in ESVs in China were more modest than the global average.

GRAPHICAL ABSTRACT



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ABSTRACT

As a result of economics and policy, land-use/land-cover change (LUCC) in China has undergone a series of complicated changes over the past three decades. However, the effects of LUCCs on ecosystem service values (ESVs) have never been previously assessed at the national scale. Thus, on the basis of three Chinese LUCC maps from 1988, 2000, and 2008, we examined changes in land-use/land-cover and consequent ESVs using a value transfer method. We found that ESVs decreased by 0.45% and 0.10% during the periods 1988–2000 and 2000–2008, respectively, and that ESV changes in China during the period 2000–2008 were relatively moderate compared to the rest of the world over a similar period. The ESVs for provision, regulation, support, and culture decreased by 0.19%, 0.48%, 0.43%, and 0.45%, respectively, during the period 1988–2000, while they decreased by 0.11%, 0.09%, 0.14%, and 0.04%, respectively, during the period 2000–2008. We also developed an elasticity indicator to assess responses in ESV change relative to LUCCs. Results of this analysis show that 1% of land conversion in China resulted in 0.15% and 0.10% average changes in ESVs during the two periods, respectively.

1. Introduction

Ecosystem services are defined as the benefits humans gain from ecosystem functions (de Groot et al., 2002; MEA, 2003; Faber and van Wensem, 2012), as well as the direct and indirect contributions of ecosystems to human well-being (TEEB, 2010; Gomez-Baggethun and Barton, 2013). Not only do ecosystems provide a great deal of materials (including food, wood, and other raw materials) but they also furnish non-material services (including carbon sequestration, water purification, and aesthetic benefits) (MEA, 2005) that are important for human survival, health, and well-being (Costanza et al., 1997; MEA,

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2005). Economic evaluation of these services can provide quantification of the benefits gained from ecosystems (Troy and Wilson, 2006; Chen and Chen, 2007; de Groot et al., 2012; Kang et al., 2016), a powerful tool to inform decision-making processes (Costanza et al., 1997, 2014; Balmford et al., 2002; Metzger et al., 2006; TEEB, 2010; Kozak et al., 2011; de Groot et al., 2012; Su et al., 2014; Song and Deng, 2015; Song et al., 2015).

Substantial efforts have been made to determine the monetary costs and benefits of ecosystem service delivery (Morse et al., 2013). For example, in 1997, Costanza et al. (1997) used a meta-analysis of studies that employed a range of market, non-market, and biophysical valuation methods to estimate global ESV to be in the range US$16 to US$54 trillion per year, with an average of US$33 trillion per year. Since then, the volume of literature on ESV assessment has grown (e.g., Vihervaara et al., 2010; de Groot et al., 2012), with many researchers utilizing the method of Costanza et al. (1997) to examine the ESVs of farmland, forest, grassland, and wetland ecosystems (Zhao et al., 2004; Li et al., 2007, 2014; Tong et al., 2007; Hu et al., 2008; Nelson et al., 2009; Gomez-Baggethun et al., 2010; Polasky et al., 2011; Zang et al., 2011; Calvet-Mir et al., 2012; Viglizzo et al., 2012; Long et al., 2014). Nevertheless, placing monetary value on ecosystem services remains a challenge that confronts all efforts to assess ESVs; because these goods and services tend to be shared, public goods that are not bought and sold, we often do not see their value through the lens of market transactions.

In practical terms, when attempting to ascertain the ESV of a given area, a number of approaches have been employed, including market price, productivity, travel cost, and benefit transfer methods (King et al., 2000). Of these approaches, the benefit transfer method assesses the economic value of ecosystem services by transferring available information (e.g., basic value) from an existing 'study site', or multiple 'study sites', to a new 'unstudied site' (de Groot et al., 2002; Gascoigne et al., 2011; Richardson et al., 2015). Benefit transfer is actually a procedure for taking the estimates of economic benefits (or values in general) gathered from one site and applying them to another (Plummer, 2009). Thus, this method assess ESVs for a study area by using monetary values pre-assigned to each biome or LUCC type, and although it has been criticized for bias in some cases, it is still commonly applied because of its feasibility (Eigenbrod et al., 2010; Lautenbach et al., 2011; Su et al., 2014). Valuations developed by Costanza et al. (1997) have been particularly widely used and divide the biosphere into 16 ecosystem and 17 service types, with ESVs estimated for each.

One issue of particular interest and importance has been determining how LUCC affects ESVs, as land is not just the locus of terrestrial natural ecosystem function, but has also been used by humans in numerous ways, with these uses influencing functions (Turner et al., 1995; Lambin et al., 1999; Kreuter et al., 2001; Hao et al., 2012). Thus, changes in LUCC have markedly affected ecosystem services worldwide (Polasky et al., 2011). For example, LUCC modifies the surface terrestrial biogeochemical cycle (Lambin and Ehrlich, 1997), and research has been conducted on the links between LUCC and ecosystem services including nutrient cycling, climate regulation (Zhao et al., 2004; Peng et al., 2006; Li et al., 2007), soil carbon (Collard and Zammit, 2006), water availability and regulation (Schroter et al., 2005; Fiquepron et al., 2013), and recreation and aesthetic value (Nahuelhual et al., 2014). This previous research has provided vital insights and guidance to land and environmental managers (Hao et al., 2012).

Costanza et al. (2014) updated their global ESV using the same method as previously applied (Costanza et al., 1997), and found that it had decreased over the period 1977–2011 by either $4.3 trillion (if assessed using their 1997 unit value), or by $20.2 trillion (if assessed using their 2011 unit value). In the central region of the Gulf of Mexico, for example, the total ESVs of Boca del Río, Chachalacas, and Costa Esmeralda decreased $1400/year, $700,000/year and $10,000/year, respectively (Mendoza-Gonzalez et al., 2012). Similar work has shown that in Leipzig, Germany, the ESV decreased by up to 23% over the period 1964–2004 (Lautenbach et al., 2011), while in Changzhou, China, the ESV decreased by 19.3% over the period 1991–2006 due to LUCC (Li et al., 2014). Although LUCC has generally been found to reduce total ESVs in many regions, it can also increase some ESVs. For example, although total ESVs on the island of Chongming, China, declined by 62% over the period 1990–2000, ESVs for water regulation, water supply, waste treatment, and raw materials increased (Zhao et al., 2004). Similar results have also been reported by Feng et al. (2012), and Mendoza-Gonzalez et al. (2012).

Globally, the most important LUCC has been the expansion of cropland and pastoral land at the expense of natural ecosystems (Lambin and Meyfroidt, 2011). For example, during the period 1980–2000, over 55% of new agricultural land across the tropics was developed at the expense of intact forests, while a further 28% came from disturbed forests (Gibbs et al., 2010). Thus, LUCC raises concerns about corresponding changes in ecosystem services and biotic diversity globally.

In China, over the past three decades, LUCC has been particularly complicated (Liu et al., 2005; Deng et al., 2006; Galic et al., 2012) as a result of fast economic growth and the adoption of several land-use policies. At the end of the 1980s, China launched the 'Reform and Opening-Up' policy, triggering fast economic development. This rapid economic development, with attendant urbanization, drove changes in LUCC including the drastic expansion of built-up areas and the loss of cultivated land (Liu and Tian, 2010; Kong, 2014). For example, the number of Chinese cities increased from 193 to 660 during the period 1978–2008 (Wu et al., 2013). At the end of the 1990s, to mitigate land degradation (in particular, soil erosion) and to improve ecological conditions, China initiated the 'Grain-For-Green' (GFG) policy, the largest land retirement and afforestation program in the country to-date, to return steeply-sloping cultivated land to forest or grassland. China also adopted the 'Cultivated Land Balance' (CLB) policy, aimed at preserving the quantity and quality of cultivated land.

Although studies have been conducted on the effects of LUCC on ecosystem services in several small regions of China (Wang et al., 2006; Feng et al., 2012; Hao et al., 2012; Liu et al., 2012; Hu et al., 2013; Wu et al., 2013; Chen et al., 2014; Li et al., 2014), to date there has been no assessment of these effects at a national scale. In addition, elasticity of ESV change in response to LUCC remains unclear. Thus, to fill these knowledge gaps, this paper aims to: (1) Examine LUCCs in China during the period 1988–2008; (2) Assess changes in ecosystem services in response to LUCCs; and (3) Discern the elasticity of ESV changes in response to LUCC.

2. Materials and methods

2.1. Assignment of ESVs

In this study, we used the framework of Costanza et al. (1997), but employed ESVs developed for China by Xie et al. (2008). As discussed above, Costanza et al. (1997) assessed the economic value of 17 ecosystem services for 16 biomes (Table 1), based on published studies and some original calculations. This work has had far-reaching effects on research in China on the economic evaluation of ecosystem services. Indeed, Chinese researchers have raised several issues that need to be addressed when the Costanza et al. (1997) framework is applied to China. For example, ESVs of cultivated land are thought to be underestimated, as these values are likely more reflective of the level of development in western countries. As a result, it is necessary to modify the Costanza et al. (1997) framework when it is applied in China.

Xie et al. (2008) developed the research of Costanza et al. (1997) focusing on two aspects. Firstly, based on the data in MEA (2003, 2005) and the understanding of ecosystem services provided by Chinese researchers, the 17 ecosystem services proposed by Costanza et al. (1997) were grouped into four types and nine sub-types (Table 1). Secondly, Xie et al. (2008) proposed the concept of equivalent value (EV) per unit area as a modification to the transferred EV of ecosystem