Technological Forecasting & Social Change xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

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

Incorporating ecosystem services into agricultural management based on land use/cover change in Northeastern China

Jinyan Zhan[a,*], Xi Chu[a], Zhihui Li[b,c,d], Siqi Jia[e], Guofeng Wang[f]

[a] State Key Laboratory of Water Environment Simulation, School of Environment, Beijing Normal University, Beijing 100875, China
[b] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[c] Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing 100101, China
[d] University of Chinese Academy of Sciences, Beijing 100049, China
[e] The Chinese university of Hong Kong, Shatin, N.T., Hong Kong, China
[f] Faculty of International Trade, Shanxi University of Finance and Economics, Taiyuan 030060, China

ARTICLE INFO

Keywords:
Value of ecosystem services
LUCC
Agricultural management
Value coefficients
Monetary units
Northeastern China

ABSTRACT

Land use/cover change (LUCC) in Northeastern China (NEC) has dynamically changed over the past several decades. However, few LUCC studies have examined the value of ecosystem services (VES) in major grain production areas involved in national food production. Measuring this process and incorporating VES into agricultural management can provide a scientific basis for environmental management and sustainable agricultural development. Thus, taking NEC as an example, based on modified value coefficients, we estimated changes in VES in response to LUCC over the past 25 years (1990–2015), and changed VES over this period were incorporated into agricultural management. We found that VES decreased by 27.24% and increased by 61.57% during the periods of 1990–2000 and 2000–2015, respectively. In addition, total VES increased by 17.55%. The decrease of VES during the period of 1990–2000 resulted from cultivated land reclamation, forest and wetland degradation. VES increase was influenced by land retirement and afforestation programs implemented in NEC. When changes in VES were incorporated into agricultural management, small farms appeared to be going down remarkably compared with those for mid-sized and large farms. Prudent agricultural management should be considered for mid-sized and large farms to ensure greater ES-related benefits to humans.

1. Introduction

Natural ecosystems sustain human life through a range of resources and processes, known collectively as ecosystem services (ES) (Daily, 1997). ES are commonly divided into four categories: provisioning (food and raw material production), supporting (water and nutrient cycling), regulating (water purification, climate regulation, erosion control), and cultural (aesthetic and spiritual benefits) (Fiquepron et al., 2013; MEA, 2005). ES are essential to human life. However, previous studies have reported important evidence of the ongoing degradation of ES, reflected in losses in biodiversity, decreasing average potential productivity, and water scarcity (Brauman et al., 2014; Deng et al., 2006; Song et al., 2017a; Yan et al., 2016). The reason of ES degradation is mainly because of human activity, which is always being reflected in LUCC. As a major means of agriculture management, LUCC plays an important role in ecosystem changes. To ameliorate the further degradation of ecosystems, there is a need to incorporate their value into the economic analyses that underpin real-world decision-making (Bateman et al., 2013; Burkhard et al., 2012; Foley et al., 2005). As agriculture is the dominant form of land management globally, reasonable decision-making process is so crucial for agricultural management. However, previous agricultural management researches focused on agricultural production factors (Zhang et al., 2016), crop yield (Johnston et al., 2015), agricultural productivity (Jin et al., 2015) and biological indicators of soil quality and soil organic matter characteristics (Veum et al., 2014). This paper attempted to incorporate ES into agricultural management corresponding to LUCC, which helps understanding agricultural management from a new perspective and give ecological processes involved in agroecosystems and agricultural production (Power, 2010; Sandhu and Wratten, 2013).

A wide variety of methods is available for valuing a range of ES to inform decision-making processes (Balmford et al., 2012; De Groot et al., 2012; Song and Deng, 2017). These methods can be divided into three types: direct market valuation, alternative market valuation (travel cost or hedonic pricing method) and simulated market valuation. Among these methods, a type of alternative market valuation

* Corresponding author.
E-mail address: zhanjy@bnu.edu.cn (J. Zhan).

https://doi.org/10.1016/j.techfore.2018.03.018
Received 30 November 2017; Received in revised form 15 March 2018; Accepted 21 March 2018
0040-1625/

proposed by Costanza et al. (1997) has been influential, involving estimation of the value of global ES based on land use and cover change (LUCC). Subsequently, many researchers have developed new methods based on Costanza et al.'s work to examine the VES related to LUCC (Deng et al., 2013; Dupras et al., 2016; Hausner et al., 2015; Lawler et al., 2014; Song and Deng, 2015). Costanza et al. (1997) calculated the monetary costs and benefits of ES delivery, in which global VES was demonstrated to have an economic value of US $33 trillion in 1995. Although this economic approach has been heavily criticized for its poor resolution because of underestimating the value of equivalent factors of VES related to LUCC (Richardson et al., 2015), it nevertheless represents the most comprehensive set of first-approximations available for quantifying the change in the value of services provided by a wide array of ecosystems globally (Kreuter et al., 2001; Sandhu and Wratten, 2013). Meanwhile, this method is still commonly applied because of its explicit definition, comprehensiveness and feasibility (Eigenbrod et al., 2010; Morse et al., 2013; Zhan, 2015; Zhao et al., 2004).

Costanza et al. (2014) provided an updated estimation based on updated unit ES valuation and land use change estimates during the period of 1977–2011, indicating that total global VES decreased by US $4.3–20.2 trillion/yr. Similar work using modified value coefficients has shown that in the Ethiopian highlands, VES in response to LUCC over the period of 1973–2012 exhibited a total loss ranging from US $19.3 million to US $45.9 million when employing global value coefficients (Kindu et al., 2016). In Yingkou, an important port city in China, the total VES drastically decreased by 17.2% between 2004 and 2014 (Li et al., 2017). There are 60% cases in which the global VES has being examined over the last 50 years. VES degradation has been indicated, with increased risks of unpredictable nonlinear changes and exacerbating poverty for certain groups of people (MEA, 2005). Globally, increasing research attention focused on determining the monetary cost of ES degradation. The central challenge to meet human needs from ecosystems while sustaining the Earth's life support systems makes it urgent to enhance efficient natural resource management for sustainable ecological and socioeconomic development (Deng et al., 2016). At present, research on the VES related to LUCC has widely developed in some hot zones such as wetlands (Camacho-Valdez et al., 2014; McDonough et al., 2014), coastal zones (Mendoza-González et al., 2012; Scholte et al., 2016; Speers et al., 2015), and rapid urbanization regions (Thiagarajah et al., 2015). However, few studies have assessed LUCC-related changes to VES in major grain producing areas involved in intensive national food production.

China has undergone rapid economic development since the major period of “reform and opening up” involved in becoming the second largest economy in the world, but this has come at the cost of widespread environmental and natural ecosystem degradation (Lü et al., 2012; Song et al., 2015; Song et al., 2017b). The Chinese government has made efforts to halt this degradation in land and ES (mainly soil erosion and dust storm) by initiating the world's largest land retirement and afforestation programs, known as the “Grain To Green Program” (GTGP) and the “Natural Forest Conservation Program” (NFCP). These government-financed programs have implemented strict regulation of land use change, aiming to improve ES by restoring forest and grassland, and helping to alleviate poverty among farmers (Li et al., 2013; Ouyang et al., 2016; Yang et al., 2013). Meanwhile, President Xi demonstrated strong political will to focus on green development to reverse the damage caused to ES (air, water and soil) in China at the 19th National Congress of the Communist Party of China.

Northeastern China (NEC) is an important area in which the GTGP and NFCP ecological programs have been carried out. Thus, the current study concentrates on NEC, which contains some of the major grain producing areas in China, and plays an important role in ensuring national food security. Balancing ecological protection and food security involves a high level of complexity and difficulty. During the 1990s, LUCC in NEC went through extensive changes and a large number of wetland and forest areas were transformed into cultivated land for grain production, with excessive exploitation and degradation of ES (Liu et al., 2005; Wang et al., 2006). This land use change indicates that intensive agricultural development can have a significant effect on the regional services and functions of ecosystems, reflecting the need for better decision-making for agricultural management. However, changes in multiple types of VES related to LUCC to aid agriculture management in NEC have received relatively minimal research attention in previous investigations (Song et al., 2012; Wang et al., 2015). Xie et al. (2008) developed the monetary method with a national coefficient based on the research approach proposed by Costanza et al. (2014), of which the coefficient was not suitable for NEC. Therefore, the current study aimed to 1) estimate LUCC in NEC during the period of 1990–2015; 2) assess the dynamic changes in VES in response to LUCC with a modified coefficients method based on the work of Costanza et al. (1997) and Xie et al. (2008); and 3) discuss the relationship between changes in VES and agricultural management patterns. From this paper, scientific basis can be provided for future sustainable development of agriculture and land use policy in NEC.

2. Study area

This study was carried out in an area of NEC located at relatively high latitudes, between 38° 42′ 53° 55′ N and 115° 32′ − 135° 09′ E (Fig. 1). This region is China's largest major grain producing area, and is considered to play an important role in Chinese food and ecological security. NEC is separated from Japan in the east by the East Sea, and bordered by Russia and the Korean peninsula to the north and southeast, respectively. Administratively, NEC includes three provinces (Jilin, Liaoning and Heilongjiang) and four municipalities of Inner Mongolia (Hulunbeier, Hinggan League, Tongliao and Chifeng). Its east-west span is approximately 1400 km, with a north-south length of approximately 1600 km, and the total land area is approximately 1.24×10^9 km^2. The rivers and lakes in this region are widely distributed, with obvious differences in topographic features, including cover by plains, hills and mountains. NEC exhibits a temperate continental monsoon climate with average annual temperatures increasing form the north to the south ranging between −6 and 11 °C. Annual precipitation ranges from 400 mm to 1000 mm and rises to the southeast, with most rain falling in July and August (Xia et al., 2016). Among the major grain producing areas in China, NEC is considered to be the area most susceptible to global environmental change. NEC has experienced an obvious warming trend, with an average surface temperature increase of 0.38 °C per decade over the past five decades (Gao and Liu, 2011; Wu et al., 2014).

The main economic activity in NEC is agriculture, and the mode of agricultural management differs with different latitudes and topography in this region. Most of the study area landscape (formerly marshland, grassland and marginal woodland) has been transformed to agriculture since the late 1970s, resulting in high growth in grain production (e.g., soybean, corn and wheat), particularly over the past 30 years. Cultivated land conversions can create positive externalities, such as economic growth, increasing agricultural production, and diversity of agricultural management with widespread adoption of agricultural mechanization and intensification (Deng et al., 2013; Deng et al., 2017; Yu et al., 2013). However, this transition has substantially increased the pressure on ES. Few studies have analyzed past VES changes related to LUCC in NEC, and detailed analyses of the mechanisms underlying the impact on agricultural management in NEC are scarce (Hao et al., 2012). Understanding land use changes and analyzing the vulnerability of ES are critical. Incorporating VES into agricultural management in NEC can provide insight into how land use might respond to a range of environmental changes (Xia et al., 2016) and improve understanding of ecological processes in agroecosystems and agricultural production.