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Review

Changing patterns and determinants of natural capital in the Yangtze River Delta of China 2000–2010

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HIGHLIGHTS

- Dynamics and driving forces of tempo-spatial change in natural capital were examined.
- Land use/land cover change and water quality degradation are dominant factors.
- Transforming economic development models, and regulating fast urban expansion
- Improving water quality, rehabilitating wetlands and implementing afforestation
- Equilibrium in population, economy and natural capital is a significant concern.

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ABSTRACT

Natural capital (NC) is crucial to human existence and human well-being. Evaluating ecosystem services on a regional scale has presented tremendous theoretical, methodological and policy challenges. This study addresses the challenges by developing an interdisciplinary methodology, based on expert knowledge, and by focusing on the Yangtze River Delta of China. It evaluates the stock of NC, analyzes the characteristics of, and identifies the key drivers for, spatial and temporal change in NC in the deltaic region from 2000 to 2010. A main contribution is the novel incorporation of remote sensing data that explains the dynamics of the spatio-temporal change in land use and a set of ecosystem service indicators derived from it. The study focuses on key indicators for key ecosystem services related to carbon sequestration, grain production and water supply. The indictors reflect the spatial heterogeneity of NC across diverse ecosystems in the region. Each indicator builds on land use configuration and land use composition information derived from 250 m 16-day MODIS and Landsat TM remote sensing data for 2000 and 2010, with adjustment parameters being constructed. The regional evaluation shows an overall degradation of ecosystem services, reducing total NC by 10.4% (or 8.44 billion yuan) in 2000–2010. The spatial distribution of NC exhibits a declining pattern from the south to the north of the delta. At the city level, 15 out of 16 major cities in the region have experienced dramatic loss of NC, and this pattern is significantly correlated with rapid urbanization, population growth and industrialization. Land use/land cover change and deteriorating water quality are dominant factors causing NC depletion, while increased grain productivity and environmental policies help offset the NC losses. Outcomes of this research are useful to policy makers to mitigate the declines in NC through balancing the growth between economy and population.

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1. Introduction

The concept of 'ecosystem services' appeared first in the 1970 report Study of Critical Environmental Problems (SCEP) (1970) to highlight their role in delivering services to humankind. This concept, however, was not recognized widely until a few years later when scholars (e.g., Holder and Ehrlich, 1974; Westman, 1977) raised concerns over the loss of biodiversity and that this loss would immediately weaken the provision of ecosystem services. In the 1990s, Daily (1997) further emphasized the importance of all aspects of ecosystem services for human societies, while Constanza et al. (1997) discussed the economic value to humanity of ecosystem services and the physical environment's capital stocks. Since the mid-1990s, extensive studies have addressed a breadth of issues about the conceptualization of ecosystem services, spanning from their classification (Constanza et al., 1997; Daily, 1997; MEA, 2005), evaluation (MEA, 2005; Naidoo et al., 2008; Tallis and Polasky, 2009), formation and impact mechanisms (Kremen, 2005; Hector and Bagchi, 2007) to the relationship between ecosystem services and human well-being (Carpenter et al., 2009; Bryan et al., 2010).

The UN Millennium Ecosystem Assessment (MEA, 2005) has been a milestone in the field of ecosystem services research. It provided a prominent framework for understanding ecosystem services, their current condition, and global trends and thus implications of ecosystem change for human populations. It formalized the definition of 'ecosystem services' by asserting that it involves both goods (products) and services (processes), such that eecosystem services are those parts of the environment and ecosystems which produce human well-being by making life both possible (by providing the basic natural resources such as land, water, food and fuel) and worth living (enabling health, security, good social relations etc.). It does this by providing natural resources, regulating ecosystems, enabling physio-chemical processes to take place and providing benefits of emotional, recreational or spiritual value.

The 'natural capital evaluation' (NCE) approach has attracted wide attention around the world due to increasing global pressure for the sustainable use of natural resources as well as the capability of 'ecosystem services' to translate complex ecological functions into a common neutral vocabulary for multidisciplinary scientific and political discussions (Vihervaara et al., 2010). The NCE approach is a useful means for reconciling economic and environmental interests by measuring the value of natural capital and integrating it into decision making. Natural capital (NC hereafter) as defined by researchers such as Constanza et al. (1997) refers to the natural environment as a capital asset, but one that extends beyond the economic notion of capital; it is an asset that includes all of nature's elements that provide environmental goods and services to people over an extended period. Since the beginning of the 21st century, NC evaluation has been widely applied to the realms of biodiversity protection (Nelson et al., 2009; Tisdell, 2011), ecological compensation (Villarroy and Puig, 2010), sustainable development (Mäler et al., 2008; Chapin et al., 2009), ecological security (Huang et al., 2007), and human well-being (Bryan et al., 2010; Carpenter et al., 2009). Studies on NC evaluation at the global (e.g., Constanza et al., 1997; MEA, 2005), national (e.g., Pan et al., 2005), regional (e.g., María et al., 2012) and landscape scales (Raymond et al., 2009) have not only increased the public awareness of ecological protection, but also constructed theoretical frameworks and operational tools for policy makers to formulate policies on ecosystem conservation. Sophisticated approaches to NC evaluation have been developed. These include the 'benefit transfer' approach (Constanza et al., 1997), 'cost–benefit analysis' approach (Carpenter et al., 2009; Wegner and Pascual, 2011), and the 'integrated valuation of environmental services and tradeoffs' model (InVEST) (Tallis et al., 2011).

However, the NC evaluation approach, a focus of this paper, still faces at least two major challenges. First, theory and analytical frameworks for analysis need to be further developed. This is because scientific understanding of ecosystem service problems is still inadequate and our knowledge about different ecosystems and human habitats remains patchy (Daily and Matson, 2008). Second, existing evaluation methods are heavily economics-oriented, and empirical studies into the formation processes and mechanisms of diverse ecosystem services require significant further research (Vihervaara et al., 2010). Methodologically, estimating NC needs to be interdisciplinary, incorporating econometrics, ecology and remote sensing. Remote sensing not only enables comprehensive, real-time and wide-scale monitoring of vegetation and water related ecosystem services, but also provides surrogate information on plant and soil characteristics in an ecosystem (Feng et al., 2010). While remote sensing is a vital tool for capturing tempo-spatial change in the ecosystems and fully reflects the spatial heterogeneity of NC change, accuracy in use of remote sensing data is largely determined by the resolution of remote sensing data, models used and the value criteria constructed for estimation of NC (Pan et al., 2005).

The Yangtze River Delta, the study area of the present paper, is located on the east coast of China, encompassing two provinces (Jiangsu, Zhejiang) and one municipality (Shanghai). The region has 1.2% of the total land area of China but supports 8.1% of the nation's population (1.34 billion) according to the 2010 China census. The region contains the nation's largest urban cluster — one that comprises 16 major cities (Fig. 1). These cities can be classified into one of four tiers groups depending on their population size, economic output, and roles in the national and regional economy (Editorial Committee of Annual Report on Development of Small and Medium-Sized Cities in China, 2010). Sitting at the First-tier, the megacity Shanghai (with a 23.02 million resident population) is the central hub of the region, while Nanjing (8 million, capital of Jiangsu) and Hangzhou (8.7 million, capital of Zhejiang) are regional major metropolitan areas. The region had the largest economic capacity in China over the period of 2000–2010, followed by another two mega-economic bodies located in the Beijing–

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