Ecological Indicators 45 (2014) 332–339

Contents lists available at ScienceDirect

Ecological Indicators

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

Spatially non-stationary response of ecosystem service value changes to urbanization in Shanghai, China

Shiliang Su[a,b,*], Delong Li[a], Yi'na Hu[a], Rui Xiao[c], Yuan Zhang[d]

[a] School of Resource and Environmental Sciences, Wuhan University, Wuhan, China
[b] Key Laboratory of Digital Mapping and Land Information Application Engineering, National Administration of Surveying, Mapping and Geoinformation, Wuhan University, Wuhan, China
[c] School of Remote Sensing and Information Engineering, Wuhan University, Wuhan, China
[d] Key Laboratory of Geographical Information Science, Ministry of Education, East China Normal University, Shanghai, China

ARTICLE INFO

Article history:
Received 11 November 2013
Received in revised form 5 March 2014
Accepted 21 April 2014

Keywords:
Ecosystem service values
Urbanization indicators
Geographically weighted regression
Land use and land cover
Proxy based approach

ABSTRACT

General declines in ecosystem service values (ESV) are acknowledged worldwide; however, rather few studies have used quantitative measurement to describe the relationship between urbanization and ESV. This paper characterized ESV changes and their relationships with urbanization in Shanghai peri-urban area (China), using the proxy based approach and geographically weighted regression (GWR). Results showed that between 1994 and 2006 total ESV decreased from 4718.1 to 3263.6 million RMB Yuan, with a net decline of 30.8%. Significant spatial autocorrelation was identified for the patterns of ESV changes. Adjacent districts exhibited similar trend of ESV changes. GWR signified that response of ESV changes to urbanization was spatially non-stationary. The obtained relationships presented identical nature but different strength in space. ESV changes were negatively correlated with urbanization indicators, suggesting that ESV would decline with economic increase and population growth. Districts with high proximity to central city and those located in the western area would experience higher rates of ESV declines as urbanization intensified. Our results demonstrated that GWR was superior to global regression in explaining relationship between ESV changes and urbanization.

1. Introduction

Ecosystems provide a diversity of services for human survival, health, and well-being (Costanza et al., 1997; Millennium Ecosystem Assessment, 2005). Monetary value evaluation of ecosystem services offers intuitive figures for people to understand the benefits obtained from ecosystems (Troy and Wilson, 2006; de Groot et al., 2012). Assessing ecosystem service values (ESV) is therefore regarded as important tool to convey the importance of ecosystems and promote economic incentives in routine conservation practices (Kozak et al., 2011; de Groot et al., 2012). Many methods have been proposed to assess ESV, and they can generally be divided into two categories: primary data based (service values were directly calculated using data from the study area) and biome or LULC (land use and land cover) proxy based (each LULC type is assigned a monetary value for corresponding ecosystem service). Though it has been criticized for generating relatively high bias in some cases, the LULC proxy based approach was still commonly applied in practice (Lautenbach et al., 2011), considering that the high costs can outweigh the benefits of the primary data based method (Eigenbrod et al., 2010).

Ecosystems sustain increasing pressures from the intensifying urbanization (Su et al., 2012; Estoque and Murayama, 2013). The worldwide prevailing urbanization has impacted the capacity of ecosystems to deliver services (Millennium Ecosystem Assessment, 2005). Facilitated by the LULC proxy based approach, declines of ESV have been identified from global scale (Millennium Ecosystem Assessment, 2005; WRI, 2007; de Groot et al., 2012) to regional and local scale (Troy and Wilson, 2006; Mendoza-González et al., 2012; Helfenstein and Kienast, 2014). The problem is that although general declines of ESV are acknowledged, rather few studies have quantified the relationship between urbanization and ESV. Wu et al. (2013) made an attempt in this regard, and relationships between two urbanization indicators (per capita gross domestic product, and total population) and regional total ESV were obtained. However, the data is very limited and the regional variations of ESV were ignored. More efforts are needed to quantitatively describe the response of ESV to urbanization.

* Corresponding author at: No. 129 Luoyv Road, Wuhan, 430079, China.
E-mail address: shiliangsu@163.com (S. Su).

http://dx.doi.org/10.1016/j.ecolind.2014.04.031
1470-160X/

The provision of ecosystem services is not evenly distributed across space, and ESV always presents obvious spatial heterogeneity (Chen et al., 2009; Kozak et al., 2011; Lautenbach et al., 2011). In this case, the actual phenomena may not be explained adequately by global regression (e.g. ordinary least squares regression (OLS)), given that the obtained global relationships are constant across space and can only reflect the average conditions (Fotheringham and Brunsdon, 1999). Besides, the spatial complexity of ecosystem services may violate the assumptions of global regression (no autocorrelated model residuals and homoscedasticity), generating problems of spatial non-stationarity and autocorrelation (Tu and Xia, 2008; Wheeler and Páez, 2010). Ecological processes generally incorporate spatial non-stationarity and autocorrelation in reality (Fortin and Payette, 2002). Local regression, the geographically weighted regression (GWR) in particular, has gradually replaced global regression for analyzing spatial relationships in ecological processes (Fotheringham and Brunsdon, 1999; Wheeler and Páez, 2010), since increasing literature has demonstrated the capability of GWR to solve the abovementioned two problems (Tu and Xia, 2008; Cardozo et al., 2012; Xiao et al., 2013).

This study attempts to quantitatively capture the dynamic response of ESV changes to urbanization in rapidly urbanizing area. Our objectives are to: (1) employ the LULC proxy based approach to analyze the spatial heterogeneity of ESV and their changes; (2) characterize the spatial autocorrelation of ESV changes; and (3) apply GWR to quantify the spatially non-stationary relationships between ESV changes and urbanization.

2. Study area

The Shanghai city lies in the middle part of Chinese eastern coast (Fig. 1), where the Yangtze River flows into the East China Sea. Covering about 6400 km^2, it extends from 120°51′E to 122°12′ E, and from 30°40′N to 31°53′N. Elevation averages 4 m with flat terrain. Shanghai has a subtropical monsoon climate, with annual mean temperature of 16.4 °C and annual rainfall of 1237 mm.

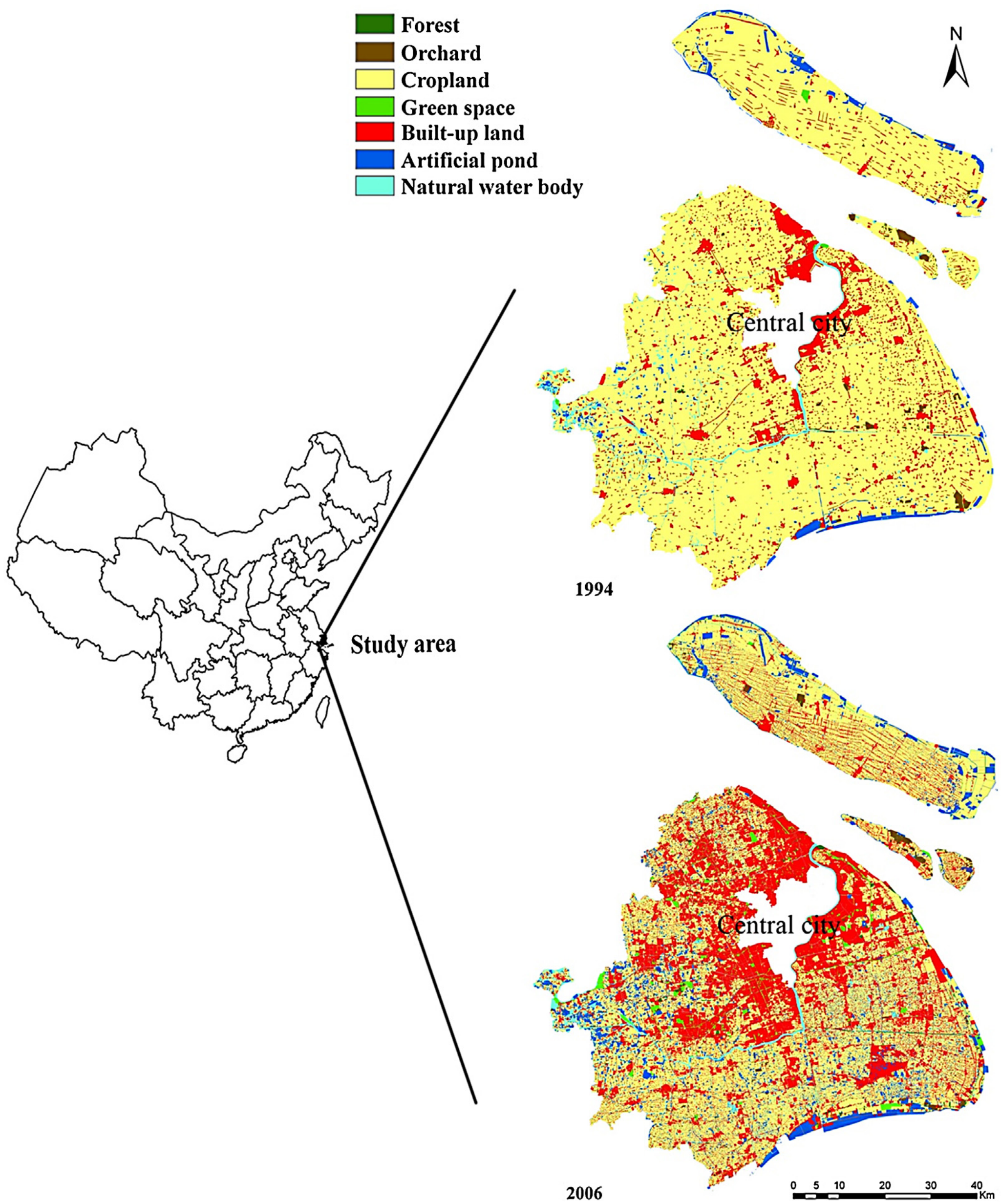

Fig. 1. Location of Shanghai peri-urban area, and land use and land cover patterns in 1994 and 2006.