Science of the Total Environment 512–513 (2015) 215–226

Contents lists available at ScienceDirect

Science of the Total Environment

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

Geographic variations of ecosystem service intensity in Fuzhou City, China

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HIGHLIGHTS

- Used ESDA and semivariance to assess geographic variations of ecosystem service
- Spatial dissimilarities in ecosystem service were observed in Fuzhou City, China.
- Used the range of semivariance as threshold to develop more precise clusters
- Land use/cover has great impacts on ecosystem services while varying by locations.

ARTICLE INFO

Article history:
Received 8 September 2014
Received in revised form 12 January 2015
Accepted 12 January 2015
Available online xxxx

Editor: E. Capri

Keywords:
Ecosystem services
Spatial autocorrelation
Semivariance analysis
Geographically weighted regression
Fuzhou City

ABSTRACT

Ecosystem services are strongly influenced by the landscape configuration of natural and human systems. So they are heterogeneous across landscapes. However lack of the knowledge of spatial variations of ecosystem services constrains the effective management and conservation of ecosystems. We presented a spatially explicit and quantitative assessment of the geographic variations in ecosystem services for the Fuzhou City in 2009 using exploratory spatial data analysis (ESDA) and semivariance analysis. Results confirmed a significant and positive spatial autocorrelation, and revealed several hot-spots and cold-spots for the spatial distribution of ecosystem service intensity (ESI) in the study area. Also the trend surface analysis indicated that the level of ESI tended to be reduced gradually from north to south and from west to east, with a trough in the urban central area, which was quite in accordance with land-use structure. A more precise cluster map was then developed using the range of lag distance, deriving from semivariance analysis, as neighborhood size instead of default value in the software of ESRI ArcGIS 10.0, and geographical clusters where population growth and land-use pressure varied significantly and positively with ESI across the city were also created by geographically weighted regression (GWR). This study has good policy implications applicable to prioritize areas for conservation or construction, and design ecological corridor to improve ecosystem service delivery to benefiting areas.

1. Introduction

Ecosystem services, the benefits people obtain from nature resources, are of irreplaceable value for humanity (Costanza et al., 1997; Millennium Ecosystem Assessment (MA), 2005). In the MA, approximately 60% of the ecosystem services are examined to be currently degraded or are being used unsustainably. Such degradation may grow significantly worse during the first half of the 21st century (Vihervaara et al., 2010). Along with the transformation and degradation of ecosystem, an increasing number of studies concerning ecosystem services have been carried out in recent years, because of their ability to reflect and communicate human–environmental interactions (Busch et al., 2012). Ecosystem service researches have focused on certain service categories, ecosystem types, and geographical areas, while substantial knowledge gaps remain concerning several aspects, e.g., the spatial variations of ecosystem services (Vihervaara et al., 2010; Syrbe and Walz, 2012). Such spatial correlations of ecosystem services have often been assumed rather than demonstrated (Troy and Wilson, 2006; Turner et al., 2007). This lack of knowledge constrains the effective management and conservation of ecosystem functioning.

Fisher et al. (2009) has pointed out that ecosystem services are not homogeneous across landscapes, nor are they static phenomena. Barbier (2012) also gives a good example highlighting the spatial variability of ecosystem services. Understanding both the spatial heterogeneity and homogeneity is indispensible in building efficient policies for governing ecosystem service production and consumption (Barrett

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http://dx.doi.org/10.1016/j.scitotenv.2015.01.035

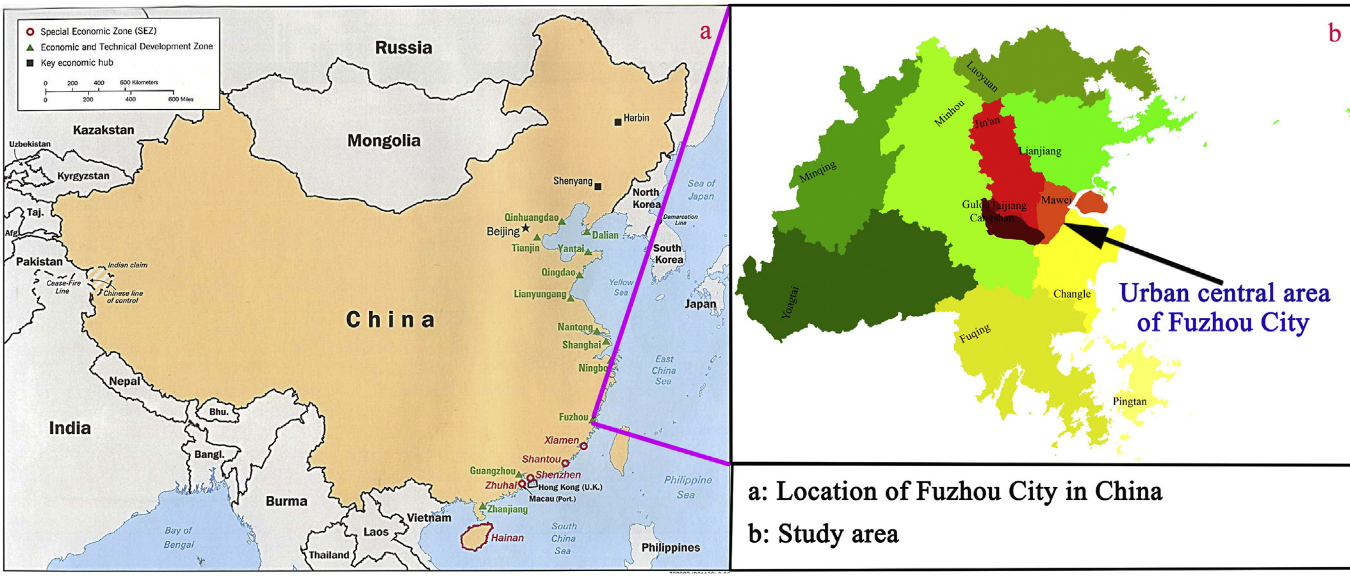

Fig. 1. Location of study area.

et al., 2011). So, researchers have increasingly sought to provide spatially explicit decision making tools for managing incentive mechanisms in ecosystem service (Nelson et al., 2009). An example provided by Kareiva and Marvier (2007) demonstrates how the mapping of social, biophysical, and ecosystem characteristics can be used to proactively prioritize ecosystem-service-based interventions and management. Despite general agreement on the spatial variability of ecosystem services, it is still not clear which type of spatial relationships (e.g., positive, negative or random) between studied observation units is and what scales do these relationships exist. At present, some methods of spatial statistic including ESDA and semivariance analysis are considered to be extremely effective ways for studying spatial characteristics (Webster and Olivier, 1990; Zawadzki et al., 2009; Zawadzki and Fabijańczyk, 2013). ESDA is a set of Geographical Information System (GIS)-based spatial statistical techniques, which can visualize the spatial agglomeration and anomalies, and reveal the activation mechanism of ecosystem services (McMillen, 2010). Measures of semivariance analysis traditionally have been used for two board purposes: quantification of the scale of variability exhibited by nature pattern of resource distributions and identification of spatial or temporal scale at which a sampled variable exhibits maximum variance (Wallace et al., 2000; He et al., 2007; Zawadzki and Fabijańczyk, 2007). Therefore, the accurate description about the spatial patterns (e.g., positive, negative or random) and gradient changes (scales) of the ecosystem services can be obtained by these two tools.

Although ecosystem services not only vary with bio-physical and social properties of the sites, but also with properties of their spatial context (Dalgaard et al., 2007), most studies address their spatial characteristics within process-related landscape units such as watersheds (Trabucchi et al., 2014), specific habitats (Barbier, 2012), or natural units (Isbell et al., 2011). Nevertheless, cause and effect areas are frequently imprecisely allocated to the processes investigated (Syrbe and Walz, 2012), due to the conflicts resulting from the mismatch between the spatial scale of the process under consideration and the scale at which measurement and observation of census variables are carried out (Anselin, 2001). Identifying the drivers of variability in ecosystem service and quantifying the range at which the variability comes to a steady manner will help scientists and managers to prioritize locations for different goals (Pijanowski et al., 2010; Su et al., 2012). For these reasons, an exploratory research on the spatial relationships between ecosystem services within administrative units and their causes has significant implications for the appropriate policy formulation and implementation. It is also methodologically important because spatial flow planning of services depends on the analysis of spatial correlation at the administrative unit level (Plummer, 2009; Serna-Chavez et al., 2014).

Just as the composition and configuration of a landscape's, biophysical features have a direct impact on the type and rate of ecosystem service provisioning, while social heterogeneity is an indirect driver in determining the adoption of conservation incentives for ecosystem services (MA, 2005; Fremier et al., 2013). Spatial complexity of ecosystem services results from the dynamic interaction between the spatial distribution of biophysical cues and variable human actions (Laterra et al., 2012; Fremier et al., 2013). Indirect drivers, such as growing of population concentrations and intensifying of economic activities, can trigger or strengthen direct drivers, such as land-use change and climate

Table 1
Classification system for land-use.

Types	Sub-types	Types	Sub-types
1 Cropland	11 Paddy field	4 Water body	44 Irrigation canals and ditches
	12 Irrigable land		45 Wetland or bottomland
	13 Dry land	5 Construction land	51 Urban land
2 Woodland	21 Forest		52 Rural settlements
	22 Shrub land		53 Transportation land
	23 Orchard, sparse and other woodland		54 Other build-up
3 Grassland	31 Weed	6 Unused land	61 Sand
4 Water body	41 River		62 Bare land
	42 Lake or pond		63 saline and alkaline land
	43 Reservoir		64 Other