

Spatial evaluation of the ecological importance based on GIS for environmental management: A case study in Xingguo county of China



Hualin Xie ^{a,*}, Guanrong Yao ^a, Guiying Liu ^b

^a Institute of Poyang Lake Eco-Economics, Jiangxi University of Finance and Economics, Nanchang 330013, China

^b School of Economics and Management, Jiangxi Agriculture University, Nanchang 330045, China

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ABSTRACT

How to assort with the relationship between the urban construction and the maintenance of ecological security is a hot issue during the process of urbanization. The purpose of this study is to identify the key ecological land maintaining ecological security and to put forward some measures for environmental management. Based on the GIS technology, from the view of water security, biodiversity conservation, disaster protection, natural recreation security, and human disturbance, an integrated index is put forward to evaluate the ecological importance of regional space. Then, a GIS-based approach for evaluating ecological importance was created, with Xingguo county of China as a case study. The results show that the area of core eco-space in the study area accounts for 30% of the total area. These areas mainly consist of the core areas of regional river systems, wetlands, nature reserves, forest parks, and scenic spots and the endangered and protected zone of geological hazards. According to the spatial characteristics of ecological importance for different regions, this study proposes some zoning regulations and measures for environmental management.

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1. Introduction

Land is fundamental to human survival and development, the sources of food and clothing, and the space carrier of human activities (Scholz et al., 2012). Land use is the process of managing and reforming land by human through a series of biological and technical means for certain economic and social purposes (Li, 1996; Vitousek et al., 1997). According to the development goals of land use management, land use types can be divided into cultivated land, construction land and ecological land and so on (see Fig. 1). As seen in Fig. 1, the conversion between different land-use types can bring conflicts between the goals of ecological protection, production, and life. Ecological land is considered as a land-use type with soil and water conservation, sand-fixing, cleaning air, provision of habitat, recreation, and other important ecological functions, and it has drawn increasing attention from many scholars (Xie et al., 2014, 2012; Yu et al., 2009). In contrast with the construction land meeting the need of urban development and the farmland supporting food security, ecological land is defined as the land resources that provide natural ecosystem services and maintain regional ecological security (Rouget et al., 2003; Xie et al.,

2014). In the past 50 years, some irrational activities of land use have made some ecological space maintaining regional ecosystem health and safety destroyed which leading to a series of ecological and environmental problems such as biodiversity reduction, soil erosion, wetland destruction, and land contamination (Vitousek et al., 1997).

The department of land management in China has not paid sufficient attention to land functions that support and maintain the stability of natural and artificial ecosystems (Xie et al., 2014). As the increasing demand for construction land, ecological land in China faces the threat of agricultural exploitation due to the land policy “cultivated land requisition–compensation balance” (Xie et al., 2014). Therefore, an urgent need to evaluate the ecological importance of regional space and to develop some measures to zoning control. This will prevent ecological issues bringing from regional development and construction, guide regional planning for sustainable development, and will carry out ecological conservation and construction.

The main objectives are to evaluate the ecological importance of space and to identify the ecological infrastructure (EI) maintaining regional security and healthy of the land. Because ecological infrastructure (EI) can provide sustainable ecosystem services for residents, and it is the rigid restrictions inviolable by urban expansion and land development (Maccagnani et al., 2013). In essence, ecological infrastructure is the natural systems for

* Corresponding author. Tel.: +86 139 7912 1643.
E-mail address: landuse2008@126.com (H. Xie).

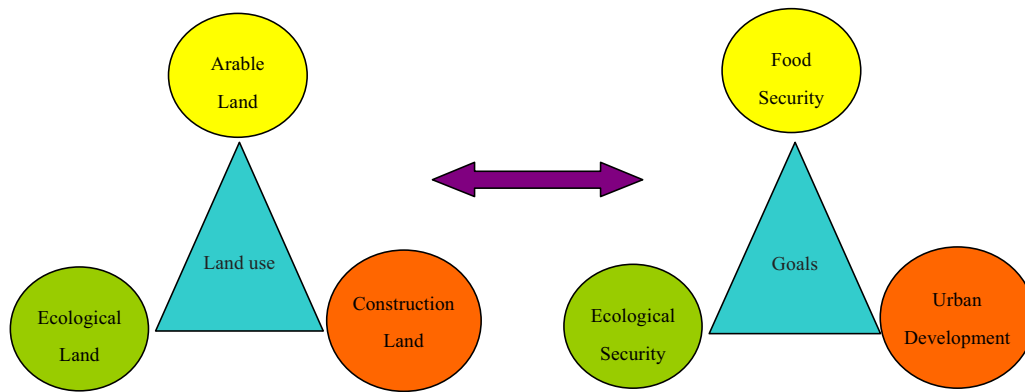


Fig. 1. Trade-offs of land use and development goal in regional space.

maintaining regional sustainable development. A new comprehensive national land use plan in China (2006–2020) has clearly outlined the requirements for eco-space, which will focus on the overall arrangements for living, life and ecological space, protect the productive land, give priority to the protection of natural eco-spaces, and promote the development of regional ecological civilization. Ecological civilization is a new concept proposed by Hu Jintao and focuses on a list of elements including the right relationship between man and nature.

The ecological evaluation based on GIS was firstly proposed by McHarg in 1960s (McHarg, 1969, 1981). In his book “*Design with Nature*”, McHarg developed the “pastry mode” of land suitability assessment (McHarg, 1969, 1981). Steinitz developed a landscape evaluation model on behalf of conservation planning ideas, namely, how to determine the biodiversity, appearance, cost, nutrition flow, public health, and other conditions (Steinitz, 1990, 1993). Steiner, McHarg’s student, proposed a model of Environmentally Sensitive Area (ESA) in 2000 (Steiner, 2000). In addition, Malczewski developed a multi-criteria method for the land suitability evaluation based on GIS (Malczewski, 2004; Malczewski et al., 2003).

Currently, the importance evaluation of ecological land has primarily focus on a single characteristic such as water security, biodiversity conservation, and soil erosion protection. For example, some studies developed a evaluation method to identify new priority areas that best meet desired the targets in combination with any existing protected areas (PAs) (Moilanen and Arponen, 2011). This method, however, is likely to produce portfolios with a large number of small and isolated protected areas (PAs), and such portfolios are less ecologically and economically feasible (Nhancale and Smith, 2011; Smith et al., 2010; Wiersma and Nudds, 2009). Some studies assessed the degree to which macroecological modelling can overcome shortfalls in our knowledge of biodiversity in tropical forests and help identify priority areas for their conservation and management (Mokany et al., 2014). Through identifying the key areas of water security, some scholars analyzed the ecological, social and economic impacts of their protection and restoration (Brouwer and van Ek, 2004). Some studies identified the key areas of soil erosion protection using GIS and Universal Soil Loss Equation (USLE) (Toumi et al., 2013). In addition, some studies on eco-space are more concerned about how to configure the eco-space to maintain the security of regional ecological environment, and mostly for these studies at small watershed scale. Seppelt took the Hunting Creek small watershed in the southern United States as the experimental area and have designed a spatial configuration scheme of land use and maximum standard amount of chemical fertilizer distribution

to control pollution caused by fertilizers using GIS and spatial differentiation model (Seppelt and Voinov, 2002).

For the importance evaluation of regional ecological space, Chinese scholars have mainly focused on ecological sensitivity and ecological suitability (He et al., 2008; Yu et al., 2008). Yu constructed a comprehensive evaluation model for ecological sensitivity based on GIS, which includes ecological protection sensitivity, ecological buffer sensitivity, landscape visual sensitivity, and ecological security sensitivity (Yu et al., 2008). The methods of ecological assessment based on GIS mainly included overlapping factors method, logical combination method (Yan et al., 2009), ecological fitness model (Ouyang et al., 1996), and minimum cumulative resistance model (Liu et al., 2010). The current studies on ecological evaluation mainly focused on the aspects of natural ecology, and the results did not reflect the spatial characteristics of regional ecosystem and maintaining ecological security.

The ecological importance evaluation of regional space is to emphasize on the harmonious development between production space, living space, and ecological space, to focus on the symbiosis between man and other organisms, and to maintain the natural foundation of urban development using applied principles in ecology. Based on the analysis of ecological characteristics, ecological importance evaluation is to explore the spatial distribution of regional ecological importance and to provide some measures for preventing ecological security issues from the regional development and construction.

The main purposes of this study are (1) to construct an integrated index at spatial scale to assess the importance of regional space maintaining water security, biodiversity conservation, disaster avoidance and protection, natural recreation, (2) to establish an GIS-based approach to identify the key space maintaining ecological security, (3) to propose some zoning regulations and measures for environmental management.

2. Materials and methods

2.1. Study area

The study area (115°01′–115°51′E, 26°03′–26°41′N) is Xingguo county in Jiangxi province of China (Fig. 2), which is located in the mid-southern areas and lies to the North of Ganzhou City, at the headwaters of Pinggu River. It is surrounded by the mountains in the east, north, and west. There is a valley basin centered in the county in the south-central, mostly lowmountains and hills. In 2005, the GDP of Xingguo totaled 3.32 billion Yuan. The proportion of three industrial structures is 39.3:31.3: 29.4, and the rural per capita net income is 2376 Yuan in 2005. The study area covers an area of 15.5 km², and the resident population was 121,000.

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