Urban Forestry & Urban Greening 19 (2016) 35–46

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

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

Modeling the optimal ecological security pattern for guiding the urban constructed land expansions

Yongxian Su[a], Xiuzhi Chen[b,*], Jishan Liao[c], Hongou Zhang[a], Changjian Wang[a], Yeyao Ye[a], Yang Wang[a]

[a] Key Lab of Guangdong for Utilization of Remote Sensing and Geographical Information System, Guangdong Open Laboratory of Geospatial Information Technology and Application, Guangzhou Institute of Geography, Guangzhou, 510070, China
[b] Key Laboratory of Vegetation Restoration and Management of Degraded Ecosystems, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, 510650, China
[c] Department of Biological Sciences, University of Notre Dame, Notre Dame, IN 46556, USA

ARTICLE INFO

Article history:
Received 17 November 2015
Received in revised form 14 June 2016
Accepted 19 June 2016
Available online 7 July 2016

Keywords:
Ecological security pattern
Constructed land expansion
Ecology protection
Cost-distance analysis
Cask principle
GIS modeling

ABSTRACT

Rapid urbanization has induced numerous ecological and environmental issues seriously threatening the ecological security. The ecological security pattern (ESP), an effective way for protecting the ecological security, is becoming increasingly important in reconciling the rapid urbanization and ecology protection in urban planning practices. Based on the cost-distance analysis method, we constructed a three-rank (basic, moderate and strict-rank) composite ESP of Gaoming (Guangdong, China) aiming at protecting the survivals and habitat securities of rare vegetations, wild animals and human beings. The proposed composite ESP is established on five equal-weighted individual ESPs (namely Geology-ESP, Hydrology-ESP, Atmosphere-ESP, Biodiversity-ESP and Farmland-ESP) for geologic disasters prevention, flood prevention and drinking water protection, air pollution prevention, biodiversity conservation and farmland protection, respectively. Our results show that under the basic, moderate, and strict- rank ESPs, the integration and connectivity of the ecological components are constantly improved, but the connectivity between neighboring urban patches decline gradually. The moderate-rank ESP proves to be the optimal spatial pattern for balancing the conflicts between urban development and ecological protection. Notably, the ESP that considers the security of atmosphere and farmland securities, which protects the regional farmlands better and well balance the expansions of industrial and residual lands, proves to be much more reasonable.

1. Introduction

Rapid urbanization has taken place worldwide during the last decades, which resulted in an unprecedented scale and rate of urban expansions and led to fundamental changes in land use and landscape pattern around the globe, especially in developing countries (Deng et al., 2009; Weng, 2007; Su et al., 2012). This has induced serious ecological and environmental issues (eg. deforestation, farmland loss, gas and water pollution) threatening the security of human beings, animals and plants (Yue et al., 2003; Elmqvist et al., 2008; Grimm et al., 2008; Tan and Abdul Hamid, 2014; Wu et al., 2014).

The ideology of ecological security is therefore raised for evaluating the basic structure and function of ecosystem whether being threatened by the urban expansions and economic developments (Solovjova, 1999; Kullenberg, 2002; Ma et al., 2004; Gong et al., 2009; Eckersley, 2005). It was firstly proposed by the federal government of the United States (Ezeonu and Ezeonu, 2000). Till now, the definition and emphasis of ecological security has been given different concepts by numerous scholars (Table 1). Among them, the ecological security is commonly defined as a kind of state that the structure and function of ecosystem are integrated, healthy and stable enough to safeguard the habitats of species and human beings, to protect the migrations of wild animals, to provide sufficient eco-services for supporting the human living and socio-economic activities (Guo, 2001; Li and Xu, 2010; Zhou and Shen, 2003).

The ecological security pattern (ESP) is therefore proposed as a new powerful tool to protect the ecological security of regional

* Corresponding author at: South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, China.
E-mail addresses: suyongxian@gdas.ac.cn (Y. Su), chenxz@scbg.ac.cn (X. Chen).

http://dx.doi.org/10.1016/j.ufug.2016.06.013
1618-8667/

Table 1
The definitions of ecological security in previous studies.

Reference	Definitions
Xiao et al. (2002)	Ecological security, including the natural, economic and social security, means the well protection of basic livelihood, the health of human life, and the ability of acclimatizing to the environment are free from threat (International Institute for Application System Analysis, 1989).
Ezeonu and Ezeonu (2000)	Ecological security refers to the states that the health and integrity of the Earth's ecosystem are well conserved, protected and restored (United States Government, 1990).
Pirages (1996)	Ecological security refers to the balances between human needs and environment affordability for sustainable development, the harmonies between human beings, wild species and micro-organisms.
Guo (2001)	Ecological security can be regarded as the status that the structure of the landscape is integrated and the function is stable to provide enough eco-services to support the development of the socio-economic system and further to maintain the human sustainable development.
Xiao et al. (2002)	Ecological security refers to the security of nature and semi-nature ecosystem, that is, the reflection of the ecosystem integrity and health, including ecological system and environment security
Chen (2002)	Ecological security means that the regional, national and global ecologies and environments of human habitats are free from stressing, damaging and even destroying. It is a state that ecosystem is healthy for sustainable development.
Zhou and Shen (2003)	Ecological security means that, in certain space-time scope, the natural, artificial and compound ecosystems maintain their basic ecological structure and the functions for supporting the sustainable social and economic activities of human beings.

Table 2
The definitions of ecological security pattern in previous studies.

Reference	Definitions
Yu (1996)	The spatial security pattern is comprised of both the strategic portions and positions of the landscape with critical significance in safeguarding and controlling certain ecological processes.
Ma et al. (2004)	The spatial security pattern is a regional-scale spatial pattern that can well protect the structure and function of ecosystem and control the regional ecological and environmental problems.
Waldheim (2006)	The ecological security pattern is comprised the non-hierarchical, flexible, and strategic elements that are essential for urban designing.
Tzoulas et al. (2007)	The ecological security pattern is a conceptual spatial pattern of green space that could protect the ecosystem health and human health.
Kattel et al. (2013)	The ecological security pattern is an ecology framework to interact ecosystems with land use, architecture and urban design, under which the green areas, roads, wetlands, 'habitat islands' and urban architecture all benefit from combining different types of urban landscapes.

ecosystem (Su et al., 2013; Berkes and Folke, 1998; Haeuber and Ringold, 1998; Devuyst et al., 2001; Ehrlich, 2002; Tzoulas et al., 2007). Several studies investigated the ESP and give similar definitions (Table 2) (Costanza, 1997; Schaeffer et al., 1998; Xiao et al., 2002; Yang and Lu, 2002). It is widely defined as the spatial pattern comprising the vital ecological components, patches and corridors of the ecosystem with critical significance in controlling the basic ecological processes (such as species migration, disaster diffusion, urban expansion etc.), protecting the structures and functions of ecosystem, and controlling the regional ecological and environmental problems (Yu, 1996; Ma et al., 2004). The most commonly used method for constructing the ESP is the GIS-based modeling approach developed by Yu (1995) based on cost-distance spatial analysis method (see method). The GIS-based modeling approach has been used for numbers of urban planning applications in the eastern, northern and southern China (Yu, 1998; Yu et al., 2005; Chen et al., 2008; Li et al., 2010; Su et al., 2012; Solovjova, 1999; Kullenberg, 2002; Ma et al., 2004; Gong et al., 2009).

Till now, ESP is becoming increasingly important in reconciling the rapid urbanization and ecology protection in urban planning practices and is attracting global attentions (Solovjova, 1999; Gong et al., 2009; Fu et al., 2010; Li et al., 2010). However, what kinds of ecological components, patches and corridors of the ecosystem should be included in ESP still remain inconsistent and need standardized by further studies (Zhao et al., 2006; Gong et al., 2009; Li et al., 2010). In general, all the vital components related to nature conservation, economic and social growth, human wellbeing and adaptive abilities with respect to ecological security should be considered in ESP (Xiao et al., 2002; Chang et al., 2011). But most previous studies mainly focused on the ecological securities in three aspects, i.e. geology, hydrology, and biodiversity, to construct the ESP. Other considerable ecological and environmental issues, i.e. air pollution and farmland degradation, caused by the urbanizations were failed to be included in most ESPs (Yu, 1995; Tzoulas et al., 2007; Li et al., 2010).

Based on the GIS-based modeling approach (Yu, 1995), we comprehensively take into account the ecological securities of the geology, hydrology, atmosphere, biodiversity and farmland, and construct the composite ESP by integrating five individual ESPs (Fig. 1), i.e., ESPs for geologic disasters prevention (Geology-ESP), flood prevention and drinking water protection (Hydrology-ESP), air pollution prevention (Atmosphere-ESP), biodiversity conservation (Biodiversity-ESP), and farmland protection (Farmland-ESP), respectively. Among the five individual ESPs, the Geology-ESP is defined as the spatial region containing the geological hazard regions as well as the potential geological hazard areas for preventing human beings from geological hazards. The Hydrology-ESP for protecting the drinking waters and preventing human beings from the flood disasters is comprised of the vital watershed regions, lakes and rivers of drinking water sources and the places where tend to be flooded. The Atmosphere-ESP is the spatial pattern preventing the ecological sources susceptible to air pollution from being damaged by the air pollutants. The Biodiversity-ESP is comprised of the key habitats of wild species and migration corridors of wild animals, while the Agriculture-ESP mainly contains the high-quality farmland and certain buffer regions. Moreover, each individual ESP has three ranks: basic rank, moderate rank and strict rank. The basic-rank ESP is only comprised of the core ecological components, patches and corridors (68% of the total), while the moderate and strict-rank ESPs are the spatial patterns that 95% and 99% of the ecological components, patches and corridors are well protected, respectively.