Ecological Indicators 94 (2018) 386–396

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

A Mamdani fuzzy inference approach for assessing ecological security in the Pearl River Delta urban agglomeration, China

J. Sun[a,b], Y.P. Li[b,c,*], P.P. Gao[a,b], B.C. Xia[d]

[a] Sino-Canada Energy and Environmental Research Center, North China Electric Power University, Beijing 102206, China
[b] School of Environment, Beijing Normal University, Beijing 100875, China
[c] Institute for Energy, Environment and Sustainable Communities, University of Regina, Regina, Sask. S4S 7H9, Canada
[d] School of Environmental Science and Engineering, Sun Yat-Sen University, Guangzhou 510275, Guangdong, China

ARTICLE INFO

Keywords:
Assessment
Ecological security
Mamdani fuzzy inference
PSR model
Urban agglomeration

ABSTRACT

In this study, a Mamdani fuzzy inference approach (MFIA) is developed for assessing ecological security of urban agglomeration. MFIA integrates pressure-state-response (PSR) model into a fuzzy logic framework, which can (1) effectively reflect the interrelationship between natural ecosystem and socio-economic systems under complex condition, and (2) capture the knowledge-based experts' judgments and tackle the imprecise and/or vague information in the urban agglomeration ecosystem. MFIA is then applied to assessing ecological security of the Pearl River Delta urban agglomeration. Among all cities, Zhaoqing owns the highest ecological security level due to its low population pressure and rich resources (e.g., forest and arable land). The ecological security level of Foshan is the lowest due to its high population pressure, limited resources, and low response level. In order to facilitate sustainable development of the urban agglomeration, various strategies for improving ecological security level should be implemented. Foshan should both control population growth and adjust industrial structure; Shenzhen and Dongguan should promote their ecological security levels through increasing forest and green areas and controlling population; for three cities of Zhaoqing, Huizhou and Jiangmen, it is essential to enhance their infrastructures for mitigating pollutant discharges and reducing the environmental pressures. The findings could help identify ecological condition of the urban agglomeration and provide useful information for supporting regional ecological planning and management.

1. Introduction

Urban agglomeration, comprising a group of cities in a specific geographical area, is a densely populated region with close economic connections (Narayana, 2011; Gu et al., 2015). In China, three main urban agglomerations (i.e. Beijing-Tianjin-Hebei, the Yangtze River Delta, and the Pearl River Delta) account for 5% of the total national urban area, 23% of the national population, and 39% of the national economy in 2016. However, along with speedy urbanization, accelerated industrialization, and extensive economic globalization, urban agglomeration expansions have changed the original ecological landscapes and threatened regional ecosystem (Caniani et al., 2016). For example, according to the national Urban-Rural Construction Statistical Yearbook, the urbanization rate of the Pearl River Delta reached 84.85% in 2016, resulting in some ecological lands being converted into constructed and industrial lands (Liu et al., 2018). The disappearing natural ecosystems (e.g., wetland, forest and water body) in the urban agglomeration have brought about a series of eco-environment problems, such as air pollution, resources exhaustion, heat island effect intensification, habitat loss, and landscape fragmentation (Qureshi et al., 2014; Lv et al., 2018). In contrast to individual city, urban agglomeration can more easily alter the ecosystem substantially in a continuous area due to decreasing or disappearing distance between cities (Du et al., 2016). Meanwhile, finding ways to guarantee the health and sustainability of regional ecosystem has become a critical task around the world.

Ecological security, as one concept to describe the conditions of structure and function of ecosystem, is used for exploring whether/how ecosystem is threatened by the urban expansion and economic development. In the past decades, numerous of mathematical approaches were developed for assessing ecological security, such as analytic hierarchy process, technique for order preference by similarity to ideal solution (TOPSIS), neural network model, ecological footprint approach, comprehensive index method, and data envelopment analysis

* Corresponding author at: School of Environment, Beijing Normal University, Beijing 100875, China.
E-mail address: yongping.li@iseis.org (Y.P. Li).

https://doi.org/10.1016/j.ecolind.2018.07.011
Received 11 June 2017; Received in revised form 1 July 2018; Accepted 5 July 2018
1470-160X/ © 2018 Elsevier Ltd. All rights reserved.

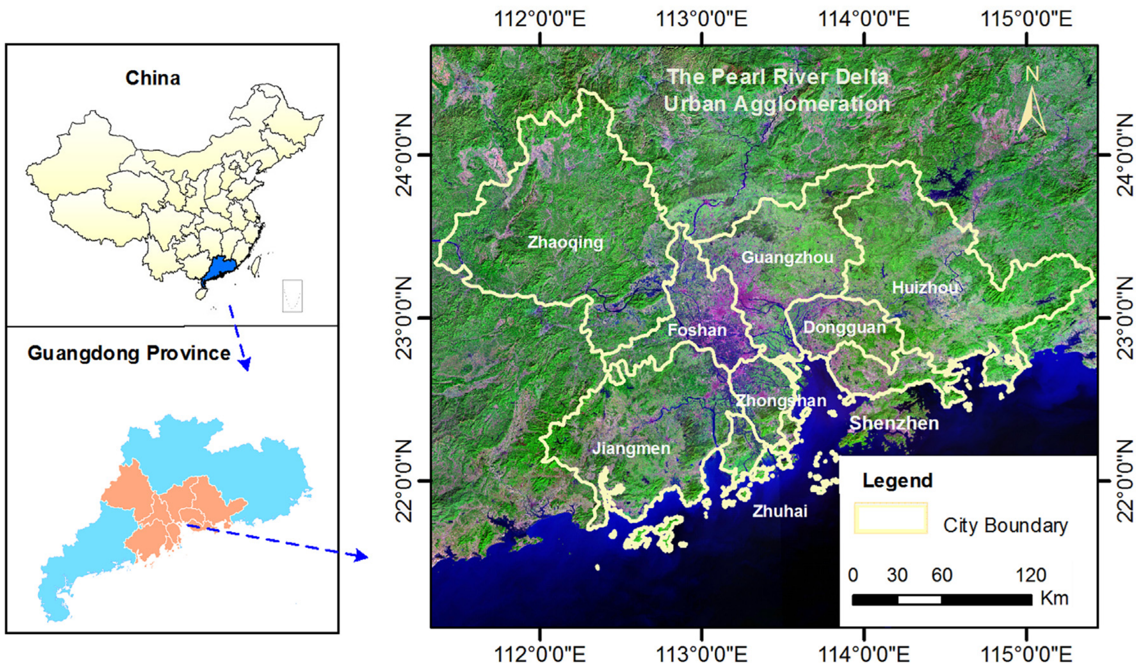

Fig. 1. The Pearl River Delta urban agglomeration.

(Estoque and Murayama, 2014; Han et al., 2015; McDonald et al., 2016). For example, Wolfslehner and Vacik (2008) combined pressure-state-response (PSR) model and analytic network method for evaluating forest ecosystem; analytic network was a promising method to reflect the interactions among human activities and natural conditions. Estoque and Murayama (2014) presented a social-ecological status index (SESI) system and weight assignment method for ranking the social-ecological status in Philippines, where the SESI was proved a neutral, complete, and robust measure for assessment. Li et al. (2014) put forward an ecological footprint method for evaluating the ecological security level of a typical steppe in China; this method was simple and reliable in revealing the regional ecological security level and the potentials for sustainable development. McDonald et al. (2016) used a Bayesian network (BN) approach for exploring the ecological risk of trophic shifts in an estuary; the BN linked available knowledge and empirical evidence to investigate the system interactions and drivers of trophic shifts. Zhou et al. (2016) advanced a TOPSIS method for exploring the spatial ecological security in Shandong, which could reveal the gap between land security and its ideal state. Most of these studies were based on the PSR model that could profoundly reflect the interactions between natural ecosystem and socio-economic system (Wilkerson et al., 2018). However, the previous studies mainly concentrated on single city ecosystem, which may not fundamentally reflect complicated ecological problems for the urban agglomeration.

In the real world, urban agglomeration is a complex system consisting of multiple components and processes (e.g., multiple cities, economics, socio-political organizations and physical factors related to the environment) (Loehle, 2004). These components change spatio-temporally and interact with each other, leading the urban agglomeration ecosystem to an intricate and nonlinear network structure. Due to the vagueness during ecosystem recognition and subjectivity in human judgements, the relationships between the ecosystem and human activities cannot be exactly quantified, resulting into fuzzy uncertainties in assessing the urban agglomeration ecological security (Li et al., 2009, 2017; Khan and Valeo, 2017). The conventional methods may be incapability of fully representing and in-depth analyzing the uncertainties and complexities of urban agglomeration ecosystem (Sun et al., 2018). Fortunately, fuzzy inference is a powerful tool to address the subjectivity, vagueness and inaccuracy in socio-economic and natural systems (Sowlat et al., 2011). The fuzzy inference is a non-linear approach that uses fuzzy rules to model the aspects of human knowledge without employing precise analysis. The method could provide a proper language to handle imprecise information through integrating qualitative and quantitative factors (Pourjavad and Shahin, 2018). Due to its flexibility and accurate estimation, fuzzy inference approach has been widely applied to complex systems and decision processes, such as water quality assessment, machinery control, and supply chain management (Shekariana and Gholizadeh, 2013; Camastra et al., 2015; Caniani et al., 2016). However, few researchers used fuzzy inference approach for assessing urban agglomeration ecosystem.

Therefore, this study is to develop a Mamdani fuzzy inference approach (MFIA) for evaluating the ecological security of the Pearl River Delta urban agglomeration. MFIA will integrate PSR model into the fuzzy logic method, which has advantages in: (i) effectively reflecting the interrelationship between natural ecosystem and socio-economic system under complex conditions; (ii) using both qualitative and quantitative factors; (iii) capturing the knowledge-based experts' judgments; and (iv) tackling the imprecise or vague information in the assessment process. Results are expected to be helpful for identifying the urban agglomeration ecological security pattern and supporting regional ecological planning and management.

2. Material and method

2.1. Study area

The Pearl River Delta urban agglomeration (between 21°17′36″N – 23°55′54″N and 111°59′42″E – 115°25′18″E) is located at the central south of Guangdong Province in southern China (as shown in Fig. 1). This region covers nine cities (i.e. Guangzhou, Shenzhen, Zhuhai, Zhongshan, Dongguan, Foshan, Jiangmen, Huizhou and Zhaoqing) with an area of approximately 54,400 km^2. As the largest agglomeration in the world in terms of both surface area and population, this region supported 4.3% of the national population (58.8 million) and contributed 9.1% of the national gross domestic products (GDP, $996.14 billion) in 2015 (Liu et al. 2018). The Pearl River Delta is subjected to a typical monsoon climate; the average annual rainfall is 1800 mm, annual sunshine can reach 2000 h, and average temperature is about

Download English Version:

https://daneshyari.com/en/article/8845081

Download Persian Version:

https://daneshyari.com/article/8845081

Daneshyari.com