



Space–time indicators in interdependent urban–environmental systems: A study on the Huai River Basin in China



YueTing Guo ^{a, b, *}, HengWei Wang ^{c, d}, Peter Nijkamp ^e, JianGang Xu ^{f, **}

^a Land Development and Reserve Bureau of Guangdong Province, Guangzhou 510635, China

^b School of Geographic and Oceanographic Sciences, Nanjing University, Nanjing 210093, China

^c College of Resources and Environments, Southwest University, Chongqing 400716, China

^d School of Public Administration and Policy, Renmin University of China, Beijing 100872, China

^e Department of Spatial Economics, VU University Amsterdam, Amsterdam, The Netherlands

^f School of Architecture and Urban Planning, Nanjing University, Nanjing 210093, China

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ABSTRACT

Cities in the Huai River Basin are experiencing rapid urbanization, which has resulted in many challenges. Based on the concept of ‘coupling’ – the interaction between the man-made urban environment and the ecological environment – this paper presents a comprehensive index system and an interlinked planning model which focuses on the nature of policy coordination between urbanization and the environment. This model is operationalized using statistical data collected from 2003, 2006, and 2009 to assess the coupling relationship between urban and environmental subsystems. Furthermore, Exploratory Spatial Data Analysis (ESDA) is applied to examine dynamic spatial patterns of impacts of both coupling and policy coordination. The results show that the degree of interdependency of the urbanization–environment system in the Huai River Basin has gradually increased over the years 2003–2006, reaching a maximum value in 2006, but decreasing thereafter. Both the degree of coupling and the degree of policy coordination appear to fluctuate over time. In the period 2003–2009, the urbanization–environment system showed always antagonistic and low coupling coordination features. The degree of both coupling and policy coordination of all cities in the area shows a positive spatial autocorrelation and similar characteristics of spatial agglomeration. This agglomeration trend is strengthening, as time goes on. In the period 2003–2009, cities of type Low–Low (LL) and type High–High (HH) occupied the dominant position in terms of number and area. Cities of type LL are mainly found in the southwest of the Huai River Basin, and cities of type HH mainly in the east and northeast. However, the difference between such cities and their neighbours is tending to decrease. In addition, there is a low number of cities of type high–low (HL) and type low–high (LH) in the Huai River Basin.

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Introduction

Urbanization is a complex process of spatial morphological change and socio-economic development. It is an essential stage that most countries experience to overcome poverty and achieve industrialization and modernization (Qiao, Fang, & Ban, 2006; Xiao, Wen, & Liu, 2010). With the continuous rise in urbanization, various contradictions and stresses between urbanization and the environment have become more serious. There is an objective dynamic

coupling interaction between urbanization and the environment. On the one hand, the accelerated process of urbanization will inevitably cause changes in the environment. These changes may be characteristic of environmental deterioration in the early stage of urbanization, but of amelioration of the environment in a later development phase of urbanization. On the other hand, environmental changes may cause changes in the level of urbanization. As the quality of the environment improves, the level and acceleration of the urbanization process is promoted, and vice versa (Fang & Yang, 2006). Hence, there is an extremely complex interactive coupling relationship between urbanization and the environment. Since the mid-20th century, environmental problems caused by rapid urbanization have attracted considerable attention from both the general public and scientific researchers. The coupling

* Corresponding author. Land Development and Reserve Bureau of Guangdong Province, Guangzhou 510635, China. Tel.: +86 20 87132517; fax: +86 20 87132519.

** Corresponding author.

E-mail addresses: guoyueting@126.com (Y. Guo), xjg129@sina.com (J. Xu).

relationship between urbanization and the environment has become a hot topic for research studies.

The Limits to Growth: A Report to The Club of Rome's Project on the Predicament of Mankind (Meadows, Meadows, & Randers, 1972) investigated for the first time environmental and resource restrictions caused by population growth and economic development at the global level. The coupling relationship between urbanization and the environment has been studied by scholars in various countries, while also fruitful research results have been obtained (Table 1). These studies mainly focus on two aspects:

- The coupling mechanism between urbanization and the environment, which involves the basic laws of the interactive coupling system of urbanization and the ecological environment (Fang, 2004; Huang & Fang, 2003). Norgaard (1990) put forward a new theory of coordinated development. He argues that a common development of the social and the ecological subsystem can take place by feedback loops. In this framework, the process of economic development is regarded as a process of constant adaptation to environmental change. In many studies, urbanization has always been regarded as a process related to the environment and safety (Brenan, 1999; Browder, 2002; Dae-Sik, Mizuno, & Kobayashi, 2003; Portnov & Safriel, 2004). Against this background, Fang and Yang (2006) have made a theoretical analysis of six basic laws governing the interactive coupling system of urbanization and the ecological environment.
- The nature and degree of coupling, including a prediction model of urbanization and the environment, which has two main research contents. The first is the environmental Kuznets curve (Grossman & Krueger, 1992; Soumyananda, 2004). Studies on the environmental Kuznets curve mainly focus on two aspects: one concerning the internal mechanism of the curve by theoretical analysis and formal testing (De Bruyn, van den Bergh, & Opschoor, 1998; Lindmark, 2002; Pasche, 2002); the other one concerning empirical analysis with respect to the factual existence of the environmental Kuznets curve. In addition, the threshold point of improved environmental quality accompanied by an increase of per capita income is simulated or predicted by a corresponding model (Andreoni & Levinson, 2001; Vrishali, 1999). The second research content of the degree of coupling involves constructing a coupling model of the urban and environmental system. The commonly used methods may contain systematic scientific methods (Forrester, 1971; Vester & Hesler, 1980), a sensitivity model (Odum & Elisabeth, 2000), an energy flow model (Sukopp & Weiler, 1988), or an econometric model (Liu, Chen, & Li, 2007).

The Huai River Basin in China is a large, independent hydrographic unit with a self-organizing system. It is an important

geographical unit which centres on resource system exploitation and the comprehensive utilization, organization and regional management of the economy (Chen, 2002). China's plan for the control and treatment of water pollution in a major river basin was first implemented in the Huai River. Since the 1980s, in the Huai River Basin, the economy has rapidly developed and the population has exploded. With the increasing rate of urbanization, the impacts of urbanization on the ecological environment, which is essential for human survival and development, are becoming increasingly significant (Qiao & Fang, 2005; Qiao, Fang, & Li, 2005). In the period of the 12th Five-Year Plan (2011–2015) for national economic and social development, under the conditions of “The eastern opening and the rise of central China”, the speed of urbanization will exceed the national average in both the East of the Longhai area and the Central Plains economic region, which are both key zones for development at the national level in the Huai River Basin. Economic development and increasing population will certainly bring enormous pressure for the improvement of the ecological environment. Therefore, research on the coupling relationship between urbanization and the environment is essential, and is of great – theoretical and practical – significance for urban governance and environmental pollution control in the process of urbanization in China. This paper aims to examine the coupling relationship between urbanization and the environment in the Huai River Basin from both exploratory and analytical perspectives. The coupling coordination degree model is adopted to quantify the degree of coupling and the degree of policy coordination of the urbanization and environment system. More specifically, Exploratory Spatial Data Analysis (ESDA), which explores temporal and spatial changes in the degree of both coupling and policy coordination between urbanization and the environment in the Huai River Basin from an exploratory perspective, is applied here for the first time in order to visualize spatial patterns in the Huai River Basin.

Materials and method

Study area

The Huai River Basin is located in eastern China, between the Yellow River and the Yangtze River, the two largest rivers in China, at longitude 111°55'–121°25' East and latitude 30°55'–36°36' North. It is West of the Tongbai Mountains and the Funiu Mountains, bounded on the South by the Dabie Mountains, the Jianghuai Hills, the Tongyang Canal, the South bank of the Rutai Canal and the Yangtze, and in the North by the South bank of the Yellow River and the Tai Mountain (Fig. 1). The Western, Southwest and Northeast areas of the Huai River Basin are mountainous and hilly. The rest consists of plains. Hilly areas and plains account, respectively, for about one-third and two-thirds of the total area. In addition, lakes and low-lying lands are scattered over the Basin. The Huai River is

Table 1
Research themes and contents of the coupling relationship between urbanization and the environment.

	Theme	Content	Case study
Coupling relationship between urbanization and the environment	Coupling mechanism	Basic laws of the interactive coupling system, the coupling mechanism, and the relationship between urbanization and the environment	Norgaard, 1990; Brenan, 1999; Browder, 2002; Dae-Sik et al., 2003; Huang & Fang, 2003; Fang, 2004; Portnov & Safriel, 2004; Fang & Yang, 2006
	Degree of coupling and prediction model	Environmental Kuznets curve	De Bruyn et al., 1998; Lindmark, 2002; Pasche, 2002
		Constructing coupling model	Internal mechanism of the Kuznets curve by theoretical analysis and formula derivation Empirical analysis on the existence of the environmental Kuznets curve Vrishali, 1999; Andreoni & Levinson, 2001 Forrester, 1971; Vester & Hesler, 1980; Sukopp & Weiler, 1988; Odum & Elisabeth, 2000; Liu et al., 2007

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