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The effects of China's Ecological Control Line policy on ecosystem services: The case of Wuhan City

Qiaoling Luo[a,b], Xiaoling Zhang[c], Zhigang Li[a], Mian Yang[d,*], Yunhua Lin[e]

[a] School of Urban Design, Wuhan University, Wuhan 430070, China
[b] Department of City and Regional Planning, The University of North Carolina at Chapel Hill, NC 27514, USA
[c] Department of Public Policy, City University of Hong Kong, City University of Hong Kong Shenzhen Research Institute, Hong Kong
[d] Economics and Management School, Wuhan University, Wuhan 430072, China
[e] College of Civil, Architecture and Environment, Hubei University of Technology, Wuhan 430068, China

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ABSTRACT

To address the pressure of the ecological degradation, an 'Ecological Control Line' (ECL) policy has been implemented in China since 2005. This paper aims to examine the effects of ECL and its supporting policies on maintaining ecosystem services within the context of Chinese high-speed economic growth and rapid urbanization. The paper is a product of previous research into the valuation of ecosystem services in monetary units and discusses a method of translation from the unit area value of China's ecosystem service value (ESV) to Wuhan City by the adjustment of the functional coefficient and economic coefficient. The evaluation of the effects of the ECL policy on ESV is divided into two time-periods. One is from 2009 to 2011 *before* the implementation of the supporting policies, and the other is from 2012 to 2014 *after* the implementation of the supporting policies. The total ESV within the Wuhan ECL area dropped by 1.54% from 2009 to 2011 and then increased quickly by 38.71% from 2012 to 2014, coinciding with the application of ECL supporting policies during 2012–2014.

1. Introduction

Ecosystem services are defined as the benefits that people derive from ecosystems, which are of fundamental importance to human well-being, health, livelihoods, and survival (Costanza et al., 1997, 2014; de Groot et al., 2012). However, as a *magnum opus* in this field, the *Millennium Ecosystem Assessment* (MEA) provided important evidence of the past and ongoing degradation of global biodiversity and ecosystem services at the beginning of the 21st century (Quintas-Soriano et al., 2016). Population agglomeration and land-use changes resulting from rapid urbanization are considered some of the most important reasons underlying the decline of regional ecosystem services (Zhang et al., 2011; Manes et al., 2016). To address the impact of urbanization on ecosystem services, urban administrators have tried to develop eco-cities or related new spaces. Of these, urban growth management has been one of the most common policies (Frenkel, 2004; Zhao et al., 2009). This can be traced back to the U.S. 19th century *City Beautiful Movement* (Ozuduru, 2014), aimed at improving the quality of the built environment in the city, and marking a pioneering effort in building urban parks, urban park systems, and metropolitan park systems. As urban sprawl has become a worldwide phenomenon (Antrop, 1998; Hammer et al., 2004), there has been a greater determination to address urban growth management. For example, London established its Green Belt policy in the 1930s (Amati and Yokohari, 2006), and the U.S. presented the Urban Growth Boundary (UGB) in the 1970s (Abbott and Margheim, 2008). In the 1990s, such notions as Green Infrastructure (GI) and Ecological Infrastructure (EI) emerged under the theme of 'smart conservation' (Benedict and McMahon, 2002; Williamson, 2003; Yu et al., 2008).

Similarly, to ease the tension between rapid urbanization and ecological sustainability, the Chinese government has made active endeavors to manage urban growth in recent years. The 'Ecological Control Line' (ECL) policy is one of the most common (Bai et al., 2016). In 2005, Shenzhen issued its *Stipulation on the Management of the Basic Ecological Control Line*, to become the first city in China to identify the basic ECLs. Later, many cities including Wuxi, Guangzhou, Dongguan, Changsha, Hefei, Wuhan, and Xiamen followed suit in adopting ECL as a public policy to ensure smart urban growth. In 2013, Guangdong province issued the *Notice on Defining ECLs in the Provincial Area* that demanded ECLs be drawn by all cities at the prefecture level. Guangdong has since become the first province in China to promote the ECL policy province-wide. Moreover, the Chinese government has

* Corresponding author.
E-mail address: yangmian909@163.com (M. Yang).

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strengthened related laws and regulations. Since 2002, the Ministry of Housing and Rural-Urban Development issued, in close sequence, stipulations on the administration of the "Four Lines" including: green lines (urban green spaces), purple lines (historic and cultural heritages), yellow lines (circulation and municipal facilities), and blue lines (surface water bodies). The boundaries, regulations, and guidance of the Four Lines must be clearly identified. In the following years, the new editions of *Urban Planning Establishment Means* (2006) and the *Urban and Rural Planning Law of the People's Republic of China* (2008) specifically demanded that development-prohibited areas be identified in urban planning as an important approach for curbing urban sprawl and preserving land resources.

Overall, three features of ECL policies can be identified in China: (1) To be a public policy for urban growth management. ECL circumscribes a regulated area with defined boundaries, in which all construction is subject to corresponding regulations. 2) To facilitate smart growth, ECL policy is an instrument to curb urban sprawl and optimize urban spatial structures by stressing orderly guidance for urban spatial development. 3) To facilitate smart preservation, ECL policy aims to protect key areas in an urban ecological pattern and stresses both the integrity of the ecological spatial network and comprehensiveness of ecosystem services. It sustains not only natural lives but also such fundamentals of urban ecological security as the urban water source reserve, the ecological reserve, basic farmland conservation, the ecological corridor, and public green spaces, all of which are linked in accordance with the principles of landscape ecology.

As countries and regions increasingly adopt urban growth management policies, it becomes important to evaluate the effects of such policies as Green Belts, UGB, and GI (Jaeger and Plantinga, 2007; Siedentop et al., 2016). Overall, urban growth management regulatory policy has its benefits and drawbacks. The benefits include regulating urban structure, improving the urban environment, improving the lives of residents (Amati and Yokohari, 2006), lowering government investment in infrastructure, preserving farmland and other ecologically sensitive areas (Gennaio et al., 2009). The drawbacks include pushing up housing prices inside the UGB (Staley and Mildner, 1999), holding back urban development (Jaeger and Plantinga, 2007), speeding up the development of land inside the UGB and around green belts (Bengston et al., 2006), and adding to travel costs and leading to non-compact leapfrog development (a development type of urban sprawl), etc. China's ECL policy has been in place for only approximately 10 years. Compared to such other urban growth management policies as UGB and EI, the ECL's different policy details may affect its role in various ways. This is especially the case in China's fast-urbanizing regions, where the contradiction between urban expansion and ecological protection is quite clear.

During the process of rapid urbanization, it is necessary to be able to quantify ecosystem services within urban areas, other than at provincial and national levels, in order to focus on their enhancement and conservation. The subject of ecosystem service quantification or valuation dates back to the early 1960s but received wide attention with the publication of Costanza et al. (1997) (De Groot et al., 2002, 2012). Since then, ESV has had many scientific applications in landscape planning, urban development planning (Estoque and Murayama, 2013; Zang et al., 2017), land use planning (Schmidt et al., 2014), urban ecosystem health assessment (Peng et al., 2015), and urban socio-economic development assessment (Zhang et al., 2017). The areas inside the ECLs (mountains, water bodies, wetlands, etc.) provide most of the ecosystem services, and the assessment of their variation reflects the area's ecological performance. However, few attempts have been made to analyze both the changes in ESV and China's urban growth management policy performance. There is, therefore, still a need for additional scientific research into integrating the assessment of ESV and urban growth management policy in the context of China's rapid urbanization.

How did urban growth management policies perform in the context of China's rapid urbanization? This paper takes a closer look at the effects of China's ECL policy on ecosystem services in the case of Wuhan City. The main objectives of our study are: 1) to explore the ESV evaluation method in relation to Wuhan and calculate the ESVs of the Wuhan ECL areas from 2009 to 2014; 2) to examine the variations of the ESVs under ECL policy during two periods, one is from 2009 to 2011 *before* the implementation of ECL supporting policies, and the other is from 2012 to 2014 *after* the implementation of ECL supporting policies; and 3) to investigate the achievements and disadvantages of existing ECL policy in the context of high-speed urbanization and a transitional economy by evaluating the actual effect of ECL and its supporting polices on ecological conservation. This helps us to provide adjustments and optimization suggestions for China's ECL policies and promote the coordinated development between urban expansion and ecological protection.

2. Study area and data sources

2.1. Study area

Wuhan is the capital city of China's Hubei province. With 166 lakes and 58 mountains, the city has rich natural resources. There is up to 2200 km^2 of lakes and rivers, which is about a quarter of the total area of the city (Wuhan Government, 2016). As a megalopolis with 10.77 million residents and 8569.15 km^2 land area as of 2016 (Wuhan Statistical Yearbooks, 2017), Wuhan is currently undergoing unprecedented high-speed growth. The urban build-up area was increased by 16.34% from 2009 to 2014, approximately 3.27% per year (Wuhan Statistical Yearbook, 2010–2015). According to *the Master Plan of Wuhan Municipality 2010–2020*, the urban build-up area will be up to 1030 km^2 by 2020. The ECLs were clearly identified in the 2009 *Master Plan of Wuhan Municipality 2010–2020* in order to mitigate the enormous pressures on the ecosystem caused by urban spatial expansion (Fig. 1), and the Wuhan government has issued a series of supporting policies since 2012 to promote the effective implementation of ECL policy (Table 1).

2.2. Data sources

Multi-temporal data is required for the ESV assessment of dynamic processes. Land-use maps were acquired for the years 2009–2014 from the Wuhan Land Resources and Planning Bureau (WLRPB). In 2009, the Ministry of Land Resources of the People's Republic of China and the National Bureau of Statistics organized the *Second National Land Survey* all over the country. The WLRPB implemented Wuhan's land use survey and set up the land use database, which has been updated every year through the land use changes survey by the WLRPB and reported to the Ministry of Land Resources of the People's Republic of China. We divided the study area into six kinds of land-use types by ArcGIS, comprising forests, farmlands, wetlands, lakes and rivers, unused lands, and construction lands (Fig. 2). Grasslands were not included because of too few grasslands in Wuhan. This was the first time that such data had been used for research into China's ECL policy evaluation.

In addition, data concerning the amount of Wuhan surface water resource was sourced from the Wuhan Municipal Water Affairs Authority, the current exchange rates from the U.S. dollar (USD) to China Yuan (CNY) were sourced from the People's Bank of China, and the data for earnings per unit area of grain cultivation was sourced from *The Data Compilation of The National Agriculture Products Costs and Profits*. All other data come from the 2010 to 2015 *China Statistical Yearbooks* and *Wuhan Statistical Yearbooks*.

3. Methods

Following the pioneering work of Costanza et al. (1997) using the value transfer method to express ESV in monetary units, studies