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Planning urban landscape to maintain key ecosystem services in a rapidly urbanizing area: A scenario analysis in the Beijing-Tianjin-Hebei urban agglomeration, China

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ABSTRACT

Planning urban landscape is essential for maintaining key ecosystem services (ESs) in rapidly urbanizing areas and has become one of the key questions in urban ecology and landscape ecology. In this study, we simulated the urban landscape dynamics in the Beijing-Tianjin-Hebei (BTH) urban agglomeration in China during the period of 2013–2040 under different ES conservation scenarios by combining ES conservation priority areas, the Land Use Scenario Dynamics-urban (LUSD-urban) model, and scenario analysis to explore approaches to planning urban landscapes with the goal of maintaining and conserving key ESs. We found that the key ESs could be effectively maintained with urban landscape planning in the BTH urban agglomeration. The loss of food production (FP) under the provisioning service conservation scenario will be 80.88% lower than that under the business-as-usual (BAU) scenario, and the loss of regulating services under the regulating service conservation scenario will be 1.42–10.34% lower than that under the BAU scenario. The loss of recreation service (RS) under the cultural service conservation scenario will be 41.52% lower than that under the BAU scenario. The integrative conservation scenario will be the best scenario to maintain ESs because the losses of FP, carbon storage (CS), water retention (WR), and air purification (AP) will be 29.31–78.49% lower than those under the BAU scenario. Protecting cropland and woodland will be an effective strategy in planning urban landscape to maintain key ESs. When cropland and woodland were protected, ES losses under the integrative conservation scenario will be 85.67–98.58% lower than those under the BAU scenario. Promoting the coordinated development of cities of different sizes will be another effective strategy in planning urban landscape. Under the best scenario of maintaining key ESs, i.e., the integrative conservation scenario, ESs in megacities and large cities can be protected, while ES losses will mainly occur in medium-sized cities. The ES losses in medium-sized cities will account for 60% of the total losses across the entire region. To ensure sustainable development in the BTH urban agglomeration, we suggest that effective policies and regulations be implemented to protect cropland and woodland areas and to promote the coordinated development of cities of different sizes to maintain key ESs.

1. Introduction

Along with global population growth and rapid socioeconomic development, urban landscapes are experiencing rapid growth around the world. During the process of urban landscape growth, multiple ecosystem services (ESs) have been negatively influenced due to the transformation of non-urban land into urban land. On the one hand, some ESs may experience evident losses due to the occupation of natural vegetation by urban land (He et al., 2014; Wu et al., 2014). On the other hand, some ESs may decrease because that the ecological processes will be altered during the continuous increase of imperious surfaces (Schroter et al., 2005). During the past 30 years, rapid urban landscape growth has caused the substantial degradation of 40% of ESs globally, which has caused negative impacts on human well-being and global sustainable development (MEA, 2005; Xie et al., 2018). Meanwhile, this kind of negative impacts will remain for next several decades

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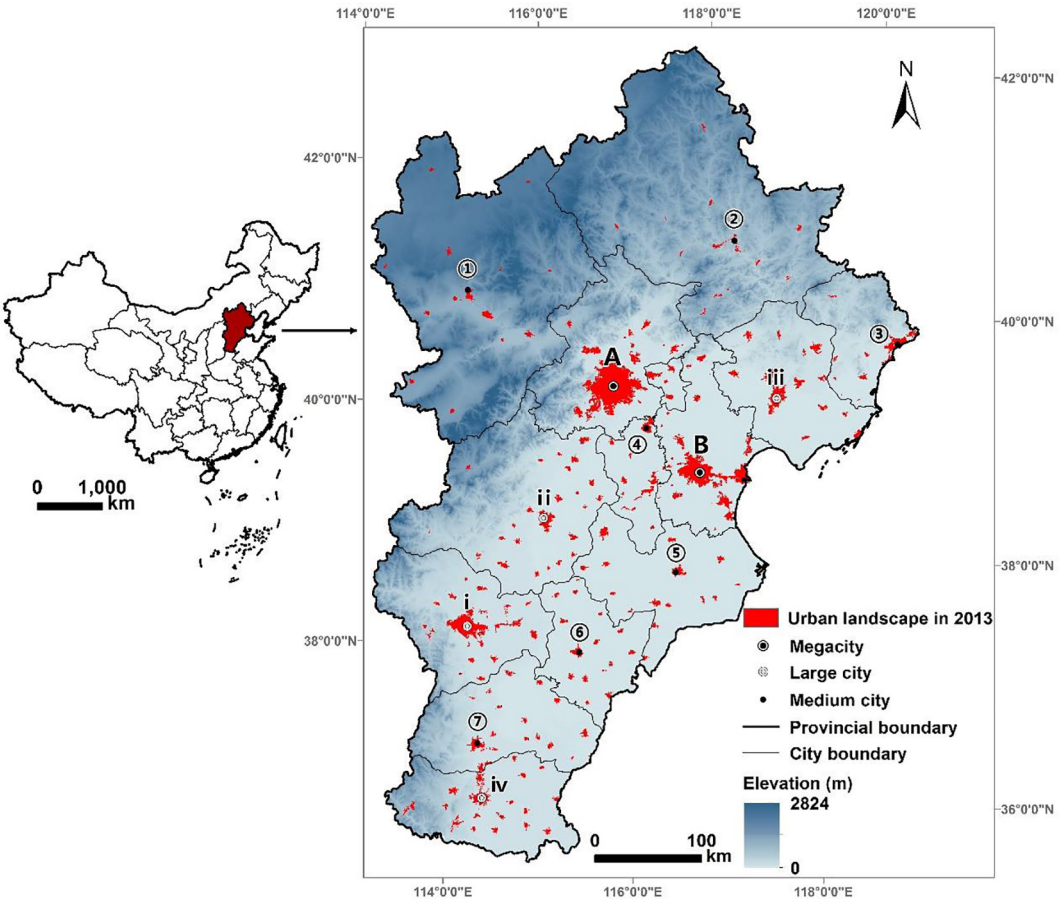

Fig. 1. The study area Notes: A and B represent Beijing and Tianjin, respectively, which are both megacities with urban population exceeding 5 million. Large cities with urban population between 1 million and 5 million include (i) Shijiazhuang, (ii) Baoding, (iii) Tangshan, and (iv) Handan. Medium-sized cities with urban population below 1 million include ① Zhangjiakou, ② Chengde, ③ Qinhuangdao,④ Langfang, ⑤ Cangzhou, ⑥ Hengshui, and ⑦ Xingtai.

(Seto et al., 2012). Therefore, planning urban landscapes to maintain key ESs has become one of the key questions in urban ecology and landscape ecology (Ahern, 2012; Hayek et al., 2016; Kain et al., 2016; Steiner, 2014; Woodruff and BenDor, 2016; Wu, 2013).

Recently, some studies have been conducted to plan urban landscapes to maintain and protect key ESs. For example, van Asselen and Verburg (2013) simulated global urban landscape dynamics from 2000 to 2040 under the constraints of crop production and livestock by using the CLUMondo model. Wang et al. (2014) forecasted urban landscape dynamics in China during the period of 2010–2020 on the basis of the maximization of the monetary value of ESs. La Rosa and Privitera (2013) presented an optimal scheme for urban landscape planning and discussed the protective effects of urban landscape planning on ESs based on the analysis of landscape patterns and land suitability in Catania, Italy. However, at least two challenges remain for related studies. First, most studies focused on estimating future urban landscape demand based on ESs, while few studies have attempted to plan and design the spatial pattern of urban landscapes under a given urban landscape demand (Pickard et al., 2016). Second, existing studies primarily explored the optimal scheme of urban landscape planning and did not fully consider the uncertainties of future urban landscape dynamics (Hu et al., 2018). Therefore, the planning of urban landscapes to effectively maintain key ESs still requires further research.

Combining ES conservation priority areas, the Land Use Scenario Dynamics-urban (LUSD-urban) model, and scenario analysis provides an effective method for urban landscape planning with the goal of ES conservation. An ES conservation priority area is a geographical area within which ESs are to be protected. In these areas, natural resources can be effectively protected, planned, developed, and utilized (Knight et al., 2008; Lv et al., 2013, 2017; Orsi and Geneletti, 2010). Several studies have used ES conservation areas to guide and formulate landscape planning schemes (Fan et al., 2016; Xu et al., 2017). The LUSD-urban model has a reliable capability to simulate future urban landscapes under different scenarios (He et al., 2006, 2015, 2017a). This model is an urban expansion simulation model, originally developed by He et al. (2006). The model can not only effectively account for the driving factors for urban landscape dynamics, but also has been successfully adopted to simulate urban landscape dynamics under different scenarios at the urban and urban agglomeration scales (He et al., 2005, 2006, 2015, 2017a). Scenario analysis refers to the process of setting a series of rational and uncertain events as scenarios, simulating the occurrence of these scenarios and analyzing their possible impacts (Alcamo et al., 2006; Swart et al., 2004). Scenario analysis can effectively account for multiple driving forces of urban landscape dynamics, consider future uncertainties, and explore the potential impacts of different policies. Therefore, scenario analysis has already been used in studies of urban landscape planning (Adams et al., 2016; Onur and Tezer, 2015).

The objective of this study was to plan urban landscapes to maintain key ESs by combining ES conservation priority areas, the LUSD-urban model, and scenario analysis in the Beijing-Tianjin-Hebei (BTH) urban agglomeration. In order to achieve this goal, we first quantified multiple key ESs and identified ES conservation priority areas in the BTH urban agglomeration, China, in 2013. Then, urban landscape dynamics under different scenarios that intended to maintain ESs from 2013 to 2040 were simulated using the LUSD-urban model. Finally, the planning paths for urban landscapes were discussed by analyzing and comparing ES conservation under different scenarios.