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Direct and indirect loss of natural habitat due to built-up area expansion: A model-based analysis for the city of Wuhan, China

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ABSTRACT

Urbanization has been responsible for the loss of cropland worldwide, especially in China. To guarantee national food security, China has implemented a series of policies to protect cropland. One of these policies requires that one-hectare cropland should be reclaimed when urban expansion occupies one-hectare cropland. Since most cropland reclamation leads to a conversion of natural habitat, such as wetland and grassland, urban expansion may lead to (indirect) natural habitat loss in addition to direct loss from conversion of into urban area. While several studies assessed the direct habitat loss resulted from built-up area expansion, few studies investigated the indirect losses caused by cropland displacement. In this paper, a model-based approach is applied to explore both direct and indirect impacts of built-up area expansion on natural habitat loss for the city of Wuhan, China, between 2010 and 2020 using different scenarios. Our scenarios differ in the implementation of strict cropland protection policies and ecosystem conservation strategies. Results show that the indirect loss of natural habitat due to cropland displacement under strict cropland protection policies far outweighs the direct loss due to built-up area expansion alone. Moreover, we found that ecosystem conservation strategies mainly influence the type of natural habitat that is affected, while the total amount of natural habitat loss remains relatively constant.

1. Introduction

Globally, the total additional land area required to meet various demands between 2000 and 2030 is estimated to range from 285 to 792 million hectares (Meyfroidt and Lambin, 2011). This comprises built-up land, pastures, cropland, and several other land uses. Thus, a significant competition for land exists between multiple different land uses and ecosystem conservation globally. Until recently, urbanization only played a minor role, due to the small amount of urban areas worldwide (van Vliet et al., 2017). However, this has changed recently due to population growth, economic development, and rural-to-urban migration. For example, between 2009 and 2050, an increase of 1.86 billion human-beings is projected in urban areas, while urban areas are expanding on average twice as fast as that of population (Angel et al., 2011; Seto et al., 2012). These competing claims on land resources are especially relevant to China, due to its large population and increasing rural-to-urban migration. The Chinese population is expected to peak between 1.45 and 1.5 billion at around the years 2025 to 2030 (Peng, 2011). Since the implementation of Open Reform Policy in 1978, China's urban population had increased from 170 million to 730 million with an urbanization level of 54% in 2013 (Wang et al., 2015). Moreover, the average annual growth rate of urban areas was 8.7% between 1992 and 2012, compared to a rate of 3.2% globally between 1990 and 2000 (He et al., 2014). As a consequence, 65 186 km^2 of urban land was added between 1992 and 2012, while 21 011 km^2 of cropland was lost in China between 2000 and 2008 (Song and Pijanowski, 2014). In the meantime, the overall environmental quality in China has deteriorated (Cao and Ye, 2013).

To mitigate cropland losses, the Chinese government has implemented a series of policies during the past four decades (Liu et al., 2017). For example, the *Cropland Balance Policy*, which aims to maintain the quantity and quality of cropland across the country (He et al., 2013; Zhong et al., 2012). In addition, six *Key State Forestry Development Programs* have been approved formally and implemented to improve the environmental quality. One of them that relates to cropland is called the *Grain for Green Policy*, which stimulates the conversion of vulnerable cropland areas back to forest. More recently, the plan of *Ecological Civilization of the 21st Century* has been developed, with the aim of securing essential natural capital and improving local livelihoods in China. Accordingly, a zoning system for ecological conservation areas

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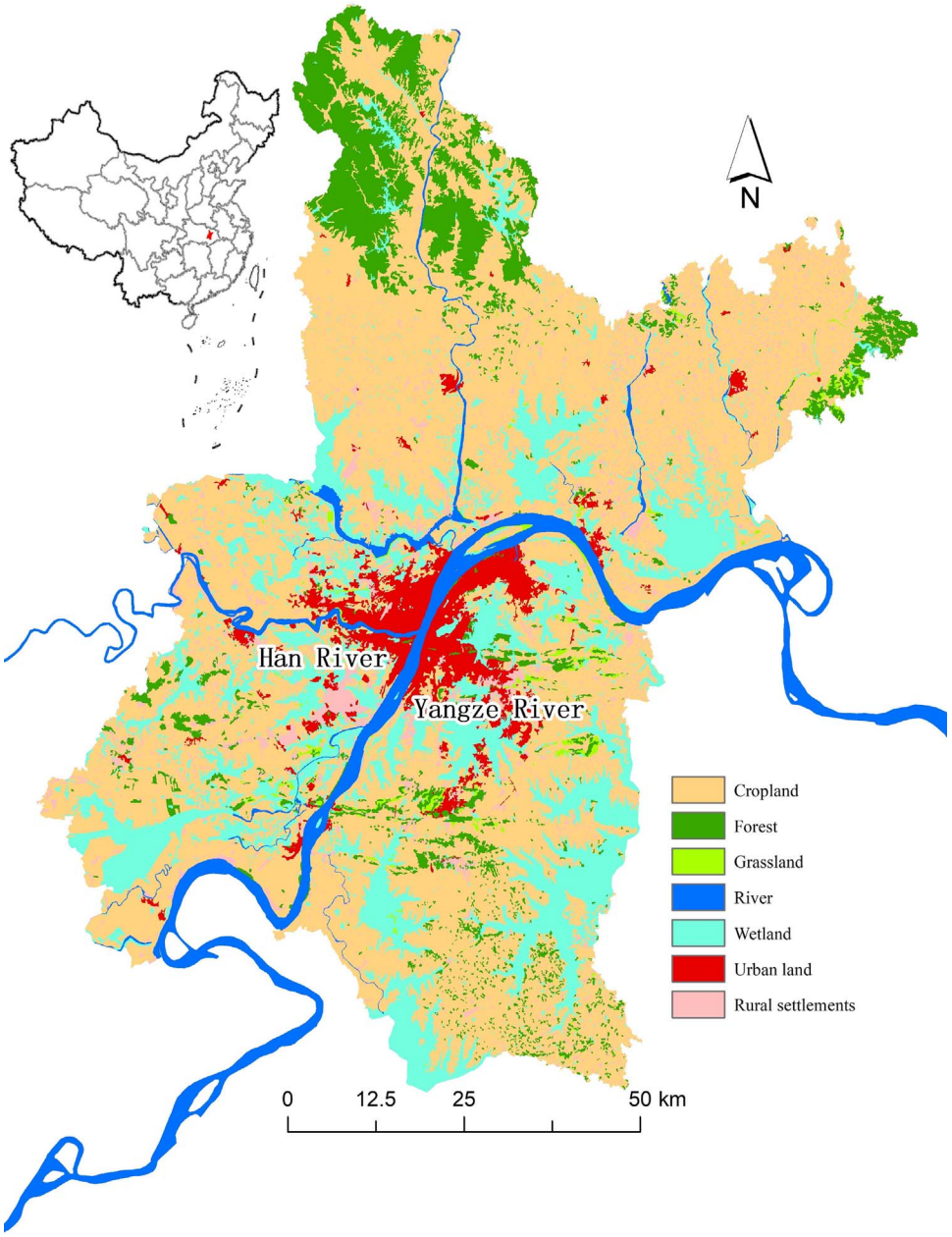

Fig. 1. Land use in the study area in 2010, and its location within China.

was introduced to achieve a balance between urban growth and economic development with nature (Daily et al., 2013; Guerry et al., 2015).

After two decades' implementation of cropland protection policies in China, the effects and performance of the policies are still doubted. Lichtenberg and Ding (2008) argued that the cropland protection may not be a necessary means to meet China's food security goals under the context of the existing institutional and policy structure. Song and Pijanowski (2014) demonstrated that cropland protection policies in China can only guarantee the balance of cropland in terms of quantity rather than quality due to the displacement of cropland to locations with inferior conditions. In addition, Zhong et al. (2012) assessed the performance of China's primary cropland protection planning and found that it was generally helpful to protect cropland in China, but failed in some areas. One study even suggested that policies aiming to preserve cropland may potentially risk an acceleration of occupying cropland because people are encouraged to move to towns and cities (Deng et al., 2015). This is consistent with an econometric analysis of the impact of land use policy, which implies a negative effect on the cropland conversion (Zhong et al., 2011).

Cropland protection, coupled with built-up area expansion, can pose both direct and indirect effects on natural habitats. "Natural habitat" here refers to those lands with non-artificial vegetation, including forest, grassland, wetlands, rocky areas and deserts, according to The Habitats Classification Scheme developed by the International Union for Conservation of Nature (IUCN, 2013). The direct impact of built-up area expansion on natural habitat loss is caused by the conversion of natural habitat into built-up area, while the indirect impacts relate to the conversion of agricultural land into built-up area and the subsequent conversion of natural habitat into agricultural land elsewhere as a compensation (van Vliet et al., 2017). Consequently, built-up area expansion may not only threaten biodiversity, but also result in the loss of terrestrial carbon stored in vegetation biomass (Seto et al., 2012). Therefore, the relation between built-up area expansion and ecosystem conservation has become increasingly important in land use management.

The loss of natural habitat caused by built-up area expansion has been discussed in several studies. McDonald et al. (2008) indicated that massive urbanization may have significant effects on the natural