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Relationship between landscape diversity and crop production: a case study in the Hebei Province of China based on multi-source data integration

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ABSTRACT

This paper explores the relationship between landscape diversity and crop production using big data techniques. In the case study area of Hebei Province, China, there is a positive ecological effect of landscape diversity on crop production (coefficient of H (Shannon's index) and H^2 on crop production are 7.9665 and −2.2388 respectively), and a negative effect via operating cultivated land change (coefficient of H and H^2 on cultivated land change are −5.4253 and 1.5520 respectively). This negative effect is measured with big data techniques and is explained by variables such as the ratio of cultivated land and other basic local conditions. The net effect of landscape diversity on crop production is negative, all else the same, reflecting the strength of the impact through cultivated land change. Thus, it is important to adhere to a certain level of landscape diversity if crop production is to be sustained.

1. Introduction

Urbanization and economic growth cause remarkable changes of landscape patterns which are identified by the mosaics of cropland, woodland, built-up land, forests, meadows, and so forth (Palacios et al., 2013). Landscape change and cultivated land conversion due to urbanization and industrial transformation can lead to severe habitat destruction as chequered landscapes are formed (Fu and Chen, 1996; Schindler et al., 2013). Dynamics of landscape patterns may alter a variety of natural flows and wildlife abundance (Romme and Knight, 1982), and also may affect crop production (Boreux et al., 2013). The phenomena seem to be more obvious in major agricultural production regions.

The Hebei Province of China, located on the periphery of Beijing and Tianjin and north of the lower reaches of the Yellow River with Bohai Sea to the east (113°27′-119° 50′E, 36°05′-42°40′N), is a salient case study of these processes (Fig. 1). Hebei Province, with an area of 190,000 km^2 and a population of 71.85 million in 2010 (10.16 million of them live in the capital city, Shijiazhuang), is one of China's major bases of agricultural production. It has a continental monsoon climate, with cold, dry winters, and hot, humid summers. The Temperature is −16 to −3 °C in January and 20–27 °C in July, with annual precipitation ranging from 400 to 800 mm, concentrated heavily in summer. Favorable climate and land resources contribute to the historical and current agriculture development, with over 80% of cropland in wheat, corn, broomcorn, millet, etc. Recent rapid urbanization witnesses the growth of the population living in urban areas in Hebei Province, which increased by 10.5 percent from 2006 to 2014. Even though it has the same increasing percentage with the entire China, Hebei Province has a faster rate since it started with a lower proportion of urban dwellers (38.8% compared with 44.3% for China, calculated by urban population divided by total population of Hebei Province) (NBSC, 2007 and 2015). The resulting land conversion changed landscape patterns and threatened crop production at both local and regional level.

While rapid urbanization and land conversion are common throughout eastern China, Hebei Province is of special interest as an

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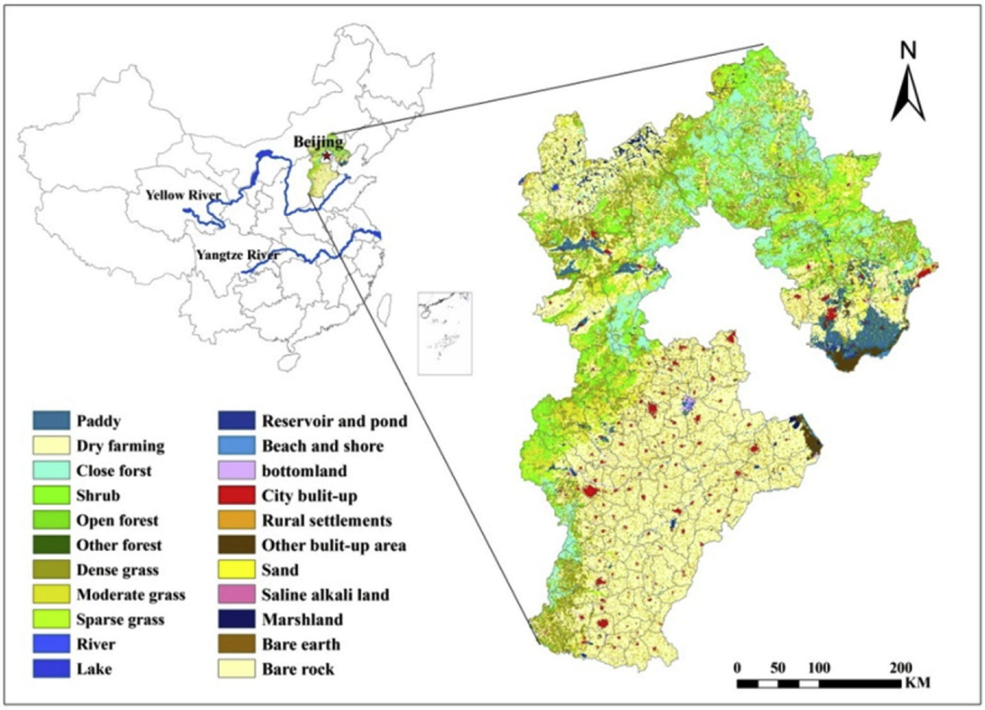

Fig. 1. The location of the study area and the patterns of land use/cover in 2008.

experimental site for industrial transformation, new urbanization and environmental friendly development (the Plan for Cooperative Development of Jing-Jin-Ji). The evolution of the industrial structure is shown by the declining importance of the primary and secondary sectors and the rise of the tertiary (services) sector; in 2010 the contribution percentage of the three sectors were 12.6%, 52.5% and 34.9%, separately, while in 2014 they were 11.7%, 51.1%, and 37.2%, separately (NBSC, 2007 and 2015). Considering the fundamental character of the primary sector, crop production is emphasized due to the limited cultivated land resources. Meanwhile, the Grain for Green Program implemented in Hebei Province has resulted in 6313 km^2 (over three percent of total land area) of cultivated land transformed to forestry land since the program launch in 2002. This ecological restoration project also affects the dynamics of landscape in Hebei Province.

1.1. *Overview of the impact of landscape diversity on crop production*

The impact of landscape diversity on crop production is ambiguous (Le Féon et al., 2010; Benoît et al., 2012; Sayer et al., 2013). On the one hand, loss of landscape diversity affects the environment due to the loss of biodiversity and the declining function of other ecosystem services (Kareiva and Wennergren, 1995; Guerry and Hunter, 2002; Midgley, 2012). The Millennium Ecosystem Assessment (MA) noted that ecosystem changes affecting food production, freshwater, timber, fuel supply that are induced by land use and land cover change (LUCC) may harm human well-being (MEA, 2005), while the Global Land Project (GLP) declared that there is a close relationship between land use change, ecosystem evolution and human production activities (GLP, 2005). The Pan-European biological and landscape diversity strategy (PEBLDS) and FAO's paradigm for enhancing productivity and sustainability all call for ecosystem approach drawing on natural contribution to agriculture (Council of Europe, 1996; FAO, 2011; Naeem et al., 2012). Peterjohn and Correll (1984) notes that landscape diversity that helps retain or transform nutrients through underground water is an essential driver of crop production. Furthermore, as nutrient flows are altered by landscape change, the crop production is affected in tandem. Petersen and Nault (2014) highlight the role of bees as mediators between landscape features and crop production. A fair summary of these studies is that the evolving landscape diversity associated with land use change influences on crop production via ecosystem services (Mace et al., 2012; Solan et al., 2008).

On the other hand, a loss of landscape diversity may occur with expansion of a certain type of land. Moreover, it is difficult to capture all aspects of diversity in a single statistic (Gorelick, 2013; Rocchini et al., 2013). For example, in Fig. 2, the landscape A is comprised of cultivated land and land use/cover type *i*, and these two types of land cover each account for 50%, separately. In contrast, landscape B has five land use/land cover types, with cultivated land accounting for 90%, and the other four combining accounting for 10%. According to the landscape metrics, commonly used to measure the landscape diversity in terms of richness and evenness (Nagendra, 2002), the landscape A is more diverse than B.

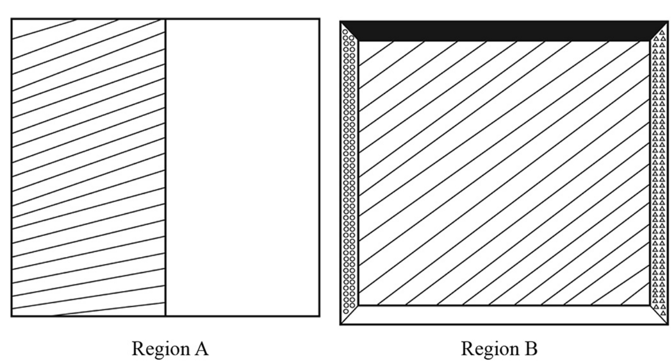

Fig. 2. The assumed landscape patterns for comparing landscape diversity and potential crop production.