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Research Paper

Mapping spatial non-stationarity of human-natural factors associated with agricultural landscape multifunctionality in Beijing–Tianjin–Hebei region, China

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ABSTRACT

Landscape services can be understood as the spatial explicit and human action produced ecosystem services at the landscape scale. Mapping multiple landscape services of agricultural land at various spatiotemporal scales can reveal the distribution and evolution of landscape services. However, further investigation into the spatiotemporal evolution and driving force of agricultural landscape multifunctionality is still needed. In this study, six landscape services (food supply, habitat maintenance, habitat connectivity, soil retention, landscape aesthetics, and population carrier) were quantified in the Beijing–Tianjin–Hebei region, China. Then, Spearman's rank correlation, partial correlation, principal component analysis and geographically weighted regression were used to identify the driving forces of agricultural landscape multifunctionality. The results showed that agricultural landscape multifunctionality generally increased during 2000–2010. The vegetation factor of NDVI was the most important natural indicator influencing landscape multifunctionality, while the gross domestic product was the most related social indicator. In a spatial non-stationary background, the vegetation component positively influenced multifunctionality; the impacts of the social component were negative in the center of the study area, but positive in the north and east. Because multifunctional landscapes are regarded as one spatial approach to achieving landscape sustainability, far more attentions should be paid to spatial non-stationarity of driving forces associated with agriculture landscape multifunctionality.

1. Introduction

Providing an important bridge between landscape ecology and sustainable development (Termorshuizen and Opdam, 2009), landscape services have always been one of the key issues in landscape ecology. Landscape services are the contributions of landscapes and landscape elements to human well-being, which can be understood as the spatial explicit and human action produced ecosystem services at the landscape scale (Bastian et al., 2014). Although landscape services are rarely a direct outcome of one precisely measured variable in space and time (Bolliger et al., 2011), the use of the term "landscape" is believed to be more appealing than "ecosystem" to non-ecological scientific disciplines (Hermann et al., 2014). At any given location, usually more than one landscape service is provided. This phenomenon shows the multifunctional character of a landscape, namely most landscapes provide multiple services, and modification of landscapes often affects individual landscape services (van der Plas et al., 2016; Willemen et al., 2012). Closely linked with landscape management, promoting multifunctionallity has become both an important direction in landscape service research and a key issue of comprehensive multidisciplinary study on landscapes from a landscape sustainability perspective (Wu, 2013, 2014).

Since 2000, the concept of multifunctionality has been widely applied in landscape evaluation, planning, and management research (Brandt, 2003; Gao et al., 2014b). Progresses have been made in evaluation and spatial identification (Rodriguez-Loinaz et al., 2015; Willemen et al., 2008), interconnectivity and evolution (Lu et al., 2014; Zheng et al., 2014), and planning and management of landscape multifunctionality (Lovell and Johnston, 2009; Lovell and Taylor, 2013; von Haaren et al., 2014). These progresses directly reflect the traditional focus in the discipline of landscape ecology on spatial human-environment interactions (Verburg et al., 2013). In particular, spatially detecting multiple landscape services is a specific quantifying expression of landscape multifunctionality, which could present the strong abundance of goods and services provided by multifunctional landscape (Crossman and Bryan, 2009; Mastrangelo et al., 2015). Kienast et al.

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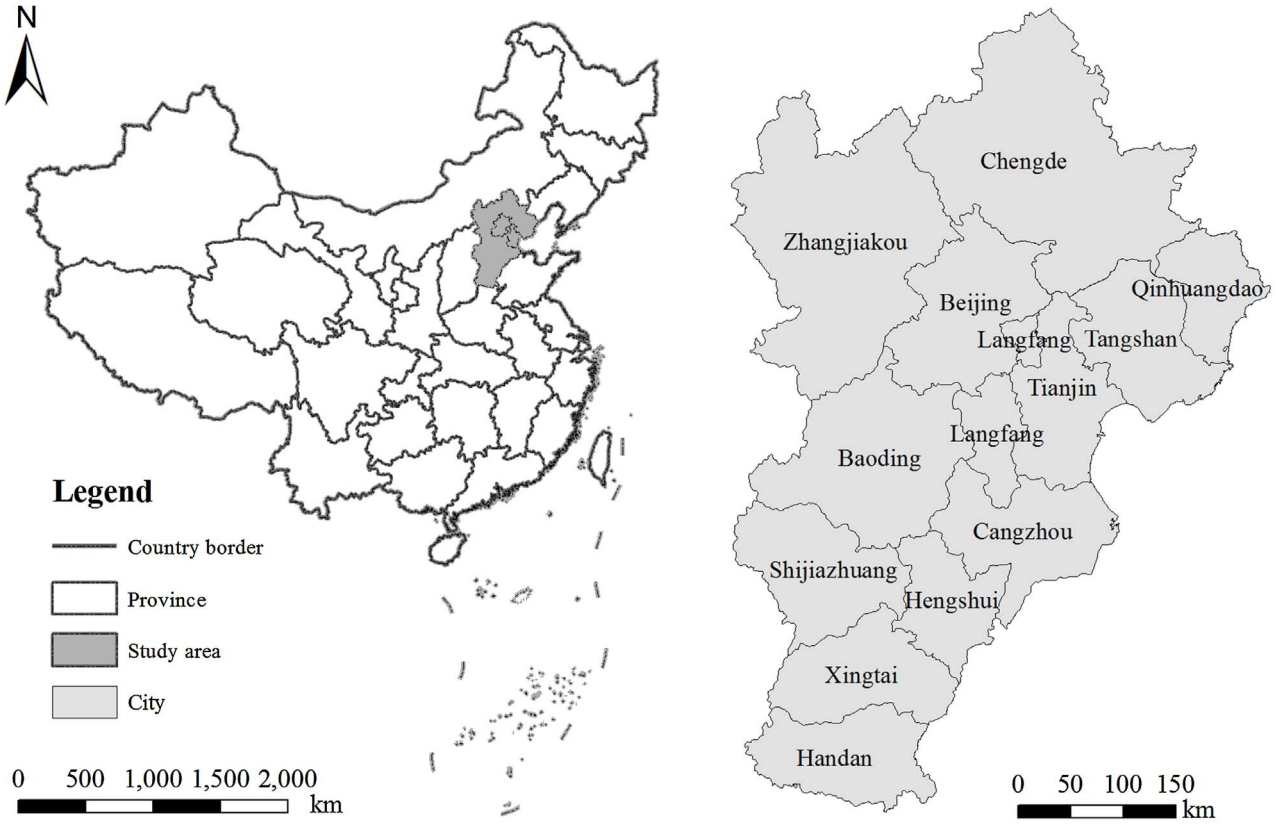

Fig. 1. Geographical location of the study area.

(2009) related the land characteristics to landscape functions (services) in 581 administrative units of Europe, and proved the linkages existed in a majority of the functions. Gulickx et al. (2013) correlated 25 kinds of landscape services from 389 ground observations with spatial characteristics in the Netherlands, and identified several spatial indicators for landscape services mapping. Mastrangelo et al. (2014) distinguished pattern-based and process-based multifunctionality, as well as highlited socially-relevant assessent. Alamgir et al. (2016) sampled three tropical forest types in Australia, and clustered the services to identify the synergies and trade-off groups. These multiple landscape services sampling, mapping and framework building approaches provided detailed understanding of landscape multifunctionality.

With increasing agricultural industrialization and urbanization, the benefits from agricultural land have expanded to various economic, ecological, and cultural approaches (Renting et al., 2009). Agricultural multifunctionality, or the ability of agriculture to provide a variety of services simultaneously, has gradually become a key element in the transformation and modernization of traditional agriculture (Waldhardt et al., 2010; Werling et al., 2014). Focusing on the spatial pattern of agricultural multifunctionality, and treating landscape as the main function source, as the branch concept of agricultural multifunctionality, agricultural landscape multifunctionality refers to the multiple landscape services of agricultural land, such as social security (Rufino et al., 2013), ecosystem conservation (Palm et al., 2014), cultural heritage (van Berkel and Verburg, 2014), and others besides the basic service of food production. Nevertheless, services other than food production have largely been ignored through social and economic development, hindering the identification of agricultural landscape multifunctionality. The lack of awareness of this multifunctionality also leads to weak protection behaviors from stockholders, as well as a decrease in farmland area, which violates the requirements of sustainable landscape management (Gonzalez-Esquivel et al., 2015; Huang et al., 2015; Robertson et al., 2014).

Studying landscape multifunctionality of agricultural land by evaluating the values of different services, identifying spatiotemporal changes in multifunctionality, and analyzing the forces that drive these changes, all play an important role in the protection of agricultural landscape services. However, few studies has focused on the spatial non-stationarity of human-natural influences driving agricultural landscape multifunctionality. The key indicators correlation with and composite influence on the distribution of agricultural landscape multifunctionality are still needed to be explored. Therefore, the introduction and improvement of various evaluation models to explore correlations between the evolution of, and spatial driving forces behind, landscape services (especially ecological and social services of agricultural land), has become a significant topic in sustainable agricultural land management (Galler et al., 2015).

Rapid urbanization accompanied by remarkable land use changes in recent years has triggered significant impacts on landscape patterns, processes, and services in China (Gao et al., 2014a; Su et al., 2012a, 2012b). Facing the decreasing vegetation covered lands and increasing ecological demands that arise from urbanization, the traditional demand for crop production has evolved to include multiple services, such as biodiversity conservation and recreation in agricultural land (Bateman et al., 2013; Cumming et al., 2014). In other words, the limited size of vegetation covered lands in highly urbanized areas increases the imperative to develop agricultural landscape services that include more than just food production. Through enhanced ecological and social services, the agricultural landscape could more comprehensively benefit human well-being.

Beijing–Tianjin–Hebei region is the political and cultural center of China and the economic core of northern China. Using the agricultural land in this region as a study area, this study spatially quantified six typical landscape services, focusing on their dynamic evolution, relationship, and factors influencing their spatial distribution and the multifunctionality. The main aims of this study included (1) quantifying the six agricultural landscape services of food supply, habitat maintenance, habitat connectivity, soil retention, landscape aesthetics, and