Applied Geography 74 (2016) 170–181

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Spatial identification of multifunctional landscapes and associated influencing factors in the Beijing-Tianjin-Hebei region, China

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ARTICLE INFO

Article history:
Received 23 September 2015
Received in revised form
7 July 2016
Accepted 18 July 2016

Keywords:
Multifunctional landscapes
Spatial identification
Landscape function interactions
Influencing factors
Beijing-Tianjin-Hebei region
China

ABSTRACT

The study of multifunctional landscapes is becoming an important subdiscipline in landscape ecology, which provides an effective approach to achieving sustainable landscape management. It is acknowledged that the development of multifunctional landscapes can meet the economic, social and ecological needs with minimal living space. This study aims to spatially identify multifunctional landscapes in the Beijing-Tianjin-Hebei region, and to make clear associated influencing factors. Based on the quantification of five landscape functions, the interactions of landscape functions were measured using spearman correlation analysis, and the cold and hot spots of landscape functions were identified through Getis-Ord Gi statistics. Based on spatial overlaying, landscape multifunctionality was assessed in the study area. Multinomial logistic regression analysis was also used to make clear the geographical factors of spatial distribution of multifunctional landscapes. The results showed that regulation functions of landscapes displayed synergies in pairs, whereas human activities had obvious conflicts with natural landscape functions, and multifunctional landscapes covered over two-thirds of the study area, widely distributing in low-elevation areas with gentle slopes. They were located not only with a usually high level of vegetation coverage and low level of urbanization, but also some distance from rivers and highways. According to clustering of landscape functions, four development zones were divided in the study area, i.e. urban assembling area, suburban grain-producing area, ecological barrier area, and rural developing area. Policy-makers should set and implement relevant economic development and ecological protection policies according to landscape function features.

1. Introduction

Under the background of global urbanization, the demand for high-quality landscapes is increasing and landscapes are expected to provide multiple functions (Stephenson, 2008; Termorshuizen & Opdam, 2009); thus, for successful landscape management, it is necessary to look at the correlation between ecological processes and landscape functions (Fu, Wang, Su, & Forsius, 2013; Li et al. 2011). The study of multifunctional landscapes can provide an effective way for landscape management, which focuses on interactions among landscape functions and thus landscape multifunctionality. Landscape functions refer to the interactions between landscape structures and ecological processes or between landscape structures themselves, and are always used to describe the ability of the landscape to provide goods and services to human society (Bastian & Lütz, 2006; Wang et al., 2014). The literatures have shown that landscape functions can be divided into four categories: production functions, regulation functions, habitat functions, and information functions (Costanza et al., 1997; de Groot, 2006; Kienast et al., 2009). Landscape compositions, structures, and ecological processes are all regarded to contribute to the potential multifunctionality of landscapes. The multifunctionality of landscapes is defined as a phenomenon whereby landscapes do or can offer a variety of material or immaterial products to meet social needs (Wiggering et al., 2006). The multifunctionality of landscapes is the foundation of multifunctional landscape research. Therefore, taking the appearance-essence relationship between landscapes and their multifunctionality into account, multifunctional landscapes are not special landscapes. Brandt and Vejre (2004) pointed out that multifunctional landscapes were

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http://dx.doi.org/10.1016/j.apgeog.2016.07.007

landscapes that simultaneously had multiple ecological, economic or social functions (services); they were natural-cultural landscapes that comprised spatial units of different levels of complex functions and integrity. At present, although there is no clear definition of multifunctional landscapes, a consensus can still be reached: multifunctional landscapes are landscapes that represent the optimal objective of landscape management.

A large number of landscape functions lack quantitative data, and are difficult to monetize; therefore, during environmental planning and policy making, decision-makers usually focus on the economic value of landscape functions alone, and transform a landscape that have several functions into a landscape with a single function (Fischer & Lindenmayer, 2007; de Groot, 2006). For example, developing a large area of land to meet growing urbanization demands can result in adverse effects on the environment and then human well-being (Su, Jiang, Zhang, & Zhang, 2011; Su, Xiao, Jiang, & Zhang, 2012; Zhou, Qian, Li, Li, & Han, 2014). Due to population expansion and the increasing pressure on natural resources and the environment, it is necessary to address our relation with the nature, and landscapes have an important role in this relation (Naveh, 2001). The development of multifunctional landscapes meets the economic, social and ecological needs with minimal living space, and will be an effective way to achieve the sustainable development of landscapes in the future (O'Farrell & Anderson, 2010; Termorshuizen & Opdam, 2009).

The traditional focus on spatial dimensions of landscape ecology has made it an important research direction for the identification of multifunctional landscapes. Given the spatial heterogeneity of landscapes, the interactions among landscapes and their internal elements will affect the ability of landscapes to provide ecosystem services in the temporal and spatial dimensions (Hinojosa & Hennermann, 2012; Portman, 2013; Wiggering et al., 2006; Willemen, Veldkamp, Verburg, Hein, & Leemans, 2012). Through the spatial identification of multifunctional landscapes, the spatial distribution of different landscape functions can be displayed, so that policy makers and planners can conduct intuitively and comprehensively a full evaluation of the combination of landscape functions in a specific region (Bolliger et al., 2011), and the anthropogenic demands can be clarified in the region. The multifunctionality of landscapes is determined by the interactions of landscape functions (Willemen, Hein, Van Mensvoort, & Verburg, 2010); based on the identity of ecosystem services and landscape functions, these interactions can be characterized as a competitive relation or a mutual synergy (Rodriguez et al., 2006; Bennett, Peterson, & Gordon, 2009). This usually depends on the identification of the conflict and synergy among landscape functions so that the interactions among them can be understood. As an important basis of multifunctional landscape identification, the identification of conflict and synergy among landscape functions can help policy-makers evaluate the impact of land-use policies on landscape functions, especially for regions that suffer from the shortage of land resources. In addition, understanding the mechanism of landscape functions' interactions will enhance our ability to sustainably manage different landscapes to provide a variety of ecological functions and services (Bennett et al., 2009; Carpenter et al., 2006).

The interdisciplinary concept of landscape multifunctionality provides a suitable platform for integrating or decomposing multiple environmental pressures on the specific landscape. This concept enables researchers to map the conflict and synergy among landscape functions, providing a more convenient and practical approach to the dissemination of scientific findings to decision-makers and wider society (Bolliger et al., 2011). It has been validated for several times that the assessment and mapping of the landscape multifunctionality provide the spatial identification of multifunctional landscapes a successful foundation (Fagerholm, Käyhkö, Ndumbaro, & Khamis, 2012; Gulickx, Verburg, Stoorvogel, Kok, & Veldkamp, 2013; Soini, 2001; Willemen, Verburg, Hein, & Van Mensvoort, 2008). The extensive application of GIS technology enriches methods for assessing landscape multifunctionality and spatial identifying multifunctional landscapes. Gimona and Van der Horst (2007) firstly identified multifunctional hotspots of agricultural landscapes in northeast Scotland; their study was based on three landscape functions: biodiversity, recreation and visual amenity. Willemen et al. (2010) quantitatively evaluated eight kinds of landscape function in the Gelderse Vallei region in Holland. By overlaying function maps, they identified multifunctional landscapes and highlighted the importance of interactions among landscape functions for landscape management. Based on the results of the spatiality of landscape functions, Wu, Feng, Gao, and Peng (2013) extracted overlaying regions with multiple landscape functions, and analyzed the distribution of multiple landscape service areas at different thresholds. However, although multifunctional landscapes have been identified based on the overlaying of landscape functions, it is in great need to make clear the formulation mechanism of spatial associations of landscape functions. As a result, it is still unknown how to construct and manage multifunctional landscapes.

The Beijing-Tianjin-Hebei region is the largest economic and most dynamic region in terms of its economy in northern China, and is also the location of Beijing City, the capital of China. This region is currently undergoing rapid urbanization, with an average urban population growth rate of 3.51% from 2000 to 2012. Due to huge population pressure, the environmental and resource issues have been highly focused in this region. However, the increase of economic living standards has also led to an increase of human demands for recreational and entertainment space. Policy-makers are looking for a win-win management approach that can ensure both economic development and environmental protection. Multifunctional landscapes is considered to be an effective approach for sustainable landscape management and planning. Therefore, taking Beijing-Tianjin-Hebei region as a case study area, multifunctional landscapes were spatially identified with a quantitative analysis of associated influencing factors. More specifically, the aims of this study were to quantify cold and hot spots of landscape functions through spatial autocorrelation analysis, to explore the interactions among landscape functions using spearman correlation analysis, to identify multifunctional landscapes through spatial overlaying, to make clear the geographical factors influencing landscape multifunctionality using multinomial logistical regression, and to conduct county-level development zoning according to spatial patterns of landscape functions and multifunctional landscapes.

2. Materials and methodology

2.1. Study area and data source

The Beijing-Tianjin-Hebei region is located in the heart of the Bohai Rim in China. Its administrative regions include two municipalities, Beijing City and Tianjin City, and 11 prefecture-level cities in Hebei Province. The overall terrain decreases in altitude from the northwest to southeast, with the Yanshan Mountains in the north of the region and plains in the center and the south (Fig. 1). Mountains and plains account for approximately 48.2% and 43.8% of the total area of the Beijing-Tianjin-Hebei region, respectively.

The region suffers from severe water shortages, with the per capita water resource only being 1/7 of the average amount in China and belonging to the absolute scarcity level according to the