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County-level patterns of cropland and their relationships with socio-economic factors in northwestern China

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ABSTRACT

Over the last several decades, the distribution of cropland in China changed as a result of nationwide urbanization, continuous economic development and rapid population growth. Patterns of cropland and the driving factors that have caused changes in those patterns differ substantially among regions. Therefore, landscape classification should be combined with an analysis of the factors that cause land-use change, especially in large areas with complex natural and socio-economic conditions. The study described here was performed in Xinjiang, a typical arid region in northwestern China. After considering the percentage of cropland, the population density and the proportion of the population that practice animal husbandry in 2008, six types of cropland patterns and attributes (TCPAs) were identified using hierarchical clustering analysis. Partial least squares regression (PLSR) models were then developed to determine the main socio-economic indicators for cropland change from 1988 to 2008 within each TCPA. The results indicated that all selected factors were significantly strong drivers of cropland change in the study area. The total power of agricultural machinery, the gross output value of agricultural products and the consumption of chemical fertilizer occurred most frequently in the six PLSR models. However, the population density of minority nationalities, the agricultural population density, the gross output value of forestry and animal husbandry products, and the oil-bearing crops yield were each identified as strong factors only once in the six models. Each variable also had different effects in each of the six groups, and significant differences existed in the composition of the main factors between the groups. The PLSR model partially eliminated co-dependency between variables and facilitated a more unbiased view of the relationships between socio-economic factors and changes in cropland. The approach used here, which combined landscape classification based on related attributes with PLSR models, has important applications in sustainable land-use management, biodiversity conservation, and agricultural land protection.

1. Introduction

Land-use change is considered to be one of the most important components of global environmental change (Johnson and Zuleta, 2013), which is often complex and related to human activities and natural ecological processes (Petit and Lambin, 2002), such as industrialization, urbanization, and population growth (Long et al., 2007). The conversion of agricultural land to non-agricultural land is a common pattern of land-use change (Yang and Li, 2000). Over the last several decades, China has experienced nationwide urbanization and economic growth as a result of economic reforms and open-door policies initiated in 1978 (Seto and Kaufmann, 2003). Since then, patterns of cropland have changed substantially in many regions, and large areas of cropland have been lost in the social and economic transition (Xu et al., 2013).

The threat of conversion to cropland also exists in many areas including arid regions. With the continuous development of society, food security has been threatened by the inappropriate planning and management of existing agricultural land resources. To overcome this problem, China has developed the most stringent farmland protection system in the world (Xu et al., 2013), mandating that the total area of cropland never falls below 180 million hectares. However, the increasing global demand for food, which is the main driver of agricultural expansion (Johnson and Zuleta, 2013), results in excess land reclamation particularly in rural and mountainous areas. Not only have natural grasslands and

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forests been replaced by croplands but also some wastelands are being transformed for economic purposes. Intensive agricultural activities could disturb natural ecosystems enormously (Sylvester et al., 2013), which is one of the major threats to biodiversity. As a result, identifying patterns of cropland and the driving factors of cropland conversions are of critical importance in intensely cultivated areas.

Five categories of driving forces have been recognized: socio-economic, political, technological, natural, and cultural driving forces (Brandt et al., 1999). The relative importance of the factors has varied from region to region (Newman et al., 2014). Many published studies have identified the driving forces of land-cover change (e.g., Bürgi and Turner, 2002; Shoyama and Braimoh, 2011; Brinkmann et al., 2012) and have focused on the effects of land-use change on ecological function and processes (e.g., Su et al., 2010; Cousins and Eriksson, 2002; Verheyen et al., 1999). Statistical approaches, including correlation analysis (Hietel et al., 2004; Krausmann et al., 2003), multi-variate analysis (Aspinall, 2004), and econometric models (Bürgi and Turner, 2002; Veldkamp and Verburg, 2004), are often used to identify land-use change based on a series of socio-economic variables. However, these studies usually regard the study area as a whole to explore the drivers of landscape changes, and rarely has such research gone on to classify the landscapes of a study area into different groups in a way that considers cropland patterns and related attributes or to explore the driving forces of change between groups.

Xinjiang is an arid region in the mid-latitude zone of northwestern China. A wide daily temperature range, high levels and durations of solar radiation, and long frost-free periods make Xinjiang one of the most intensely cultivated areas. Since China built its national economy on the agriculture foundation since early time, Xinjiang, as a highly cultivated province, experienced rapid rural transformation. Building a new countryside in China is a kind of macroeconomic development strategy aiming at rural restructuring under globalization (Long et al., 2010). The rural economic transformation mainly focuses on the agricultural infrastructure or production technology improvements. Other strategies, such as developing modern and characteristic agriculture, strengthening agricultural and rural development, have resulted in tremendous changes in the rural population (Long et al., 2011). In this context, the cropland in Xinjiang changed a lot under a series of driving forces. During the past several decades, land use change in Xinjiang Province mainly took the form of cropland expansion and grassland contraction, and cropland expansion was the major cause for grassland contraction (Zhu, 2013). The net increase in cropland from 1988 to 1998 was 2348.3 km^2, and the area of conversion to cropland from 1998 to 2008 was 8138.4 km^2, which was much higher than the first 10 years.

The aim of this study was to identify the characteristics of cropland patterns and the driving factors of cropland change in Xinjiang Province using clustering analysis and partial least squares regression (PLSR). Our specific objectives were (i) to classify the counties in Xinjiang Province with respect to the proportion of cropland, the population density, and the proportion of the population that practice animal husbandry; (ii) to explore the characteristics of each type of cropland pattern and attribute (TCPA); and (iii) to develop PLSR models that identify the main determinants of cropland change for each TCPA. The results of this study enable researchers and managers to establish effective conservation and management strategies for agricultural land resources in different parts of a region. The approach described here could also be applied to other regions with complex environmental conditions.

2. Materials and methods

2.1. Study area

The study area is Xinjiang Province (34.3°N–49.5°N, 73.5°E–96.3°E), which is located in northwestern China and has a total cropland area of 4124,563.7 ha (Fig. 1). Xinjiang, lying far from oceans in the hinterland of Eurasia, is an extremely arid region in the mid-latitude zone (Luo et al., 2006). More than 50% of the province's total area is covered by deserts (Mamtimin et al., 2011), with a low percent coverage of desert vegetation (Li et al., 2013). In addition, 29% of the region is covered by alpine meadows and dry-steppe (Anwar, 2006), and 1% is covered by forests. Only approximately 4.3% of the total area is covered by agricultural oases, which are mainly located on alluvial fans (Mamtimin et al., 2011; Li et al., 2013). Elevations within Xinjiang range widely from 155 to 8611 m due to complex topographical patterns, with the Altai, Tian Shan, and Kunlun Mountains ranging from north to south. Two major basins lie between these three mountain ranges; the northern Junggar Basin consists of mostly steppe and semi-desert environments, and the southern Tarim Basin is covered largely by desert ecosystems (Wu et al., 2010). This pattern creates a typical central Asian landscape with both mountainous and basin topography. Tian Shan divides Xinjiang into northern and southern sub-regions with distinct climate conditions (Li et al., 2013). Southern Xinjiang has 200–220 frost-free days per year, while the

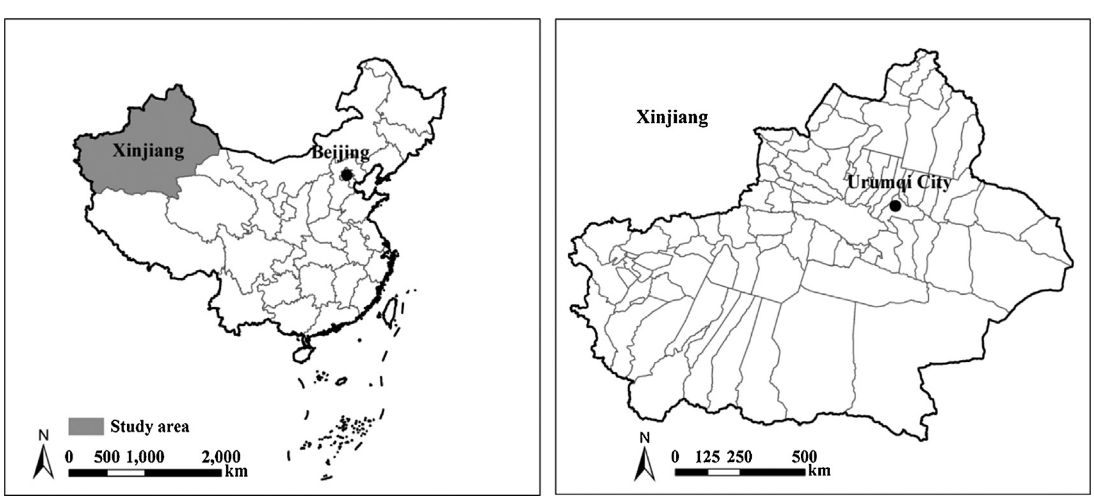

Fig. 1. Location of the study area.