

## Landscape pattern and transition under natural and anthropogenic disturbance in an arid region of northwestern China



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### ABSTRACT

There is a pressing need to determine the relationships between driving variables and landscape transformations. Human activities shape landscapes and turn them into complex assemblages of highly diverse structures. Other factors, including climate and topography, also play significant roles in landscape transitions, and identifying the interactions among the variables is critical to environmental management. This study analyzed the configurations and spatial-temporal processes of landscape changes from 1998 to 2011 under different anthropogenic disturbances, identified the main variables that determine the landscape patterns and transitions, and quantified the relationships between pairs of driver sets. Landsat images of Baicheng and Tekes from 1998, 2006 and 2011 were used to classify landscapes by supervised classification. Redundancy analysis (RDA) and variation partitioning were performed to identify the main driving forces and to quantify the unique, shared, and total explained variation of the sets of variables. The results indicate that the proportions of otherwise identical landscapes in Baicheng and Tekes were very different. The area of the grassland in Tekes was much larger than that of the cropland; however, the differences between the grassland and cropland in Baicheng were not as pronounced. Much of the grassland in Tekes was located in an area that was near residents, whereas most of the grassland in Baicheng was far from residents. The slope, elevation, annual precipitation, annual temperature, and distance to the nearest resident were strong driving forces influencing the patterns and transitions of the landscapes. The results of the variation partitioning indicated complex interrelationships among all of the pairs of driver sets. All of the variable sets had significant explanatory roles, most of which had both unique and shared variations with the others. The results of this study can assist policy makers and planners in implementing sustainable landscape management and effective protection strategies.

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### 1. Introduction

Land use in China has changed dramatically since the adoption of economic reforms and the opening-up policy in 1978 (Xu, 2004). Unprecedented urban expansion represents an important type of land transition (Seto and Fragkias, 2005). A large proportion of the land has been degraded by agricultural enterprises and overgrazing. Fragmentation of cropland, due to the construction of the

countryside (Long and Li, 2005), has caused many concerns regarding China's food security. The principal consequences of landscape changes are resource depletion and environmental and ecological problems (Imhoff et al., 2004), such as the loss, fragmentation and degradation of the available habitat for most species, which are among the major threats to biodiversity worldwide (Johnson and Zuleta, 2013; Maeda et al., 2011). These problems have had complicated influences on the modernization of China (Liu et al., 2010a). Therefore, efforts to understand the processes of landscape dynamics and driving forces are critical.

Human-induced changes to natural landscapes constitute the main driving forces of land-cover change at the local, regional and global scales (Walker et al., 2004; Etter et al., 2006; Wyman and Stein, 2010). Human disturbances, such as pollution, alteration, fire, grazing, cutting, and cultivation, in particular, are complex and

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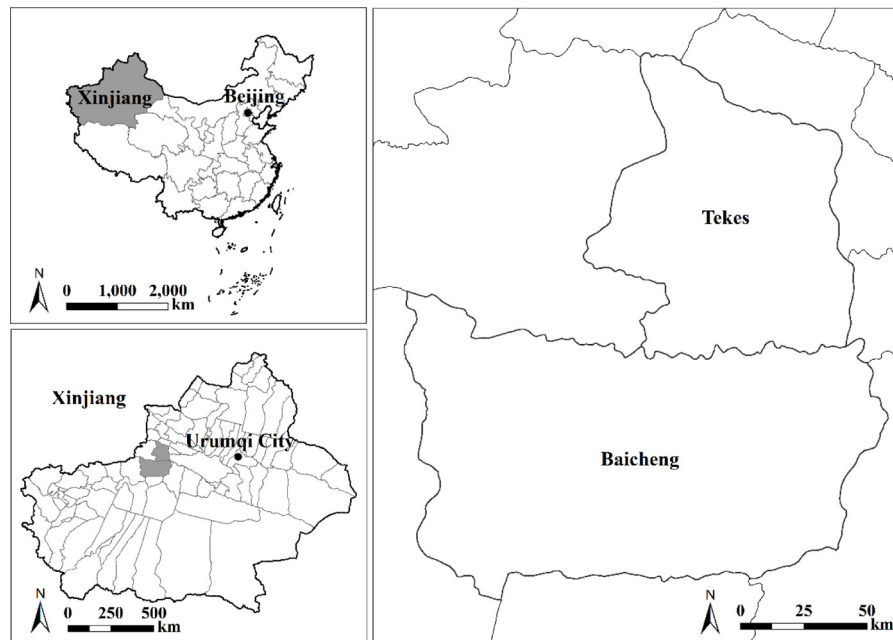


Fig. 1. Location of the study area.

reflect temporal and spatial shifts in systems of land use (Paudel and Yuan, 2012; Tzanopoulos and Vogiatzakis, 2011). The *Random House dictionary* (1987) defines culture as the sum total of ways of living developed by a group of human beings and transmitted from one generation to another. Ethnic culture is a complicated entity comprising knowledge, belief, art, morality, regulations, conventions and all types of abilities and customs that the members have acquired (Shi, 1995). In a context where one ethnic group currently represents a small minority of the residents and the residents of another ethnic group make new demands on the environmental, social and cultural functions of landscapes, landscape transitions are often at the root of the tensions between different ethnic groups.

Some researchers have attempted to depict the nature, direction, frequency, and rate of change (Krausmann et al., 2003; Lambin et al., 2003); others have focused on describing the driving forces from a historical point of view (Bicík et al., 2001; Bürgi, 1999). However, studies that use systematic methods to investigate how anthropogenic disturbances influence the pattern and change of landscapes with populations of different cultural backgrounds are rare. There are 56 ethnic groups in China, and 47 in Xinjiang Province, including 12 permanent minorities. Baicheng and Tekes are located in Xinjiang Province. Each ethnic group has its own cultural background, making these two counties typical and ideal places for studying human-caused disturbances.

The drivers of landscape changes, which are always interrelated and covarying, can be grouped into logical driver sets. Each driver set can be identified as having both unique influences that cannot be attributed to other factors and shared explanatory power due to their interrelated roles (Fisichelli et al., 2013). Attention can be paid to single variables when other covarying factors are partially driving trends (Legendre and Legendre, 1998). The confounded relationships among the factors of landscape changes need to be quantified in order to better understand the mechanism of the variables.

In the present study, multi-temporal Landsat images were used to explore landscape changes through analysis of patterns, rates of transition and drivers and quantification of the relationships between pairs of driver sets. The specific objectives were as follows: (a) to characterize the configuration and the main spatial-temporal processes of landscape changes from 1998 to 2011 under different

anthropogenic disturbances, (b) to identify the main variables that determine landscape patterns and transitions, and (c) to examine and quantify the explanatory relationships between anthropogenic disturbances and other driver sets.

## 2. Materials and methods

### 2.1. Characteristics of the study sites

The study sites were Baicheng and Tekes, two adjacent counties in Xinjiang Province in northwestern China (Fig. 1) and have similar geographical conditions.

Baicheng is a county in the northwestern Akesu Prefecture, which is located in the southern foothills in the middle of the Tianshan Mountains. Baicheng lies between latitude  $41^{\circ}24'$  and  $42^{\circ}51'N$  and stretches between longitude  $80^{\circ}37'$  and  $83^{\circ}03'E$ , with an area of  $15,917\text{ km}^2$  and elevations ranging from 1041 to 6289 m. Baicheng has a temperate continental monsoon climate with cold winters and cool summers. According to weather records, the average annual temperature is  $7.6^{\circ}\text{C}$  and the daily minimum and maximum temperatures are  $-28^{\circ}\text{C}$  and  $38.3^{\circ}\text{C}$ , respectively. The average annual rainfall is 171.13 mm. Baicheng is surrounded by mountains, forming a banded basin. The geographic conditions are complex, with natural steep slopes. The total population of Baicheng County was 189,000 in 1998 and 230,900 in 2011 (Xinjiang Province Statistical Bureau, 1999, 2012).

Tekes is a county in the southwestern Ili Kazak Autonomous Prefecture, which is situated in the northern foothills of the fold belt of Tianshan Mountain. Tekes lies between latitude  $42^{\circ}22'$  and  $43^{\circ}25'N$  and stretches between longitude  $81^{\circ}19'$  and  $82^{\circ}37'E$ , with an area of  $8080\text{ km}^2$  and elevations ranging from 924 to 4853 m. Tekes belongs to the inversion belt control area and has a typical temperate continental climate with an average annual rainfall of 383 mm. The average annual temperature is  $5.3^{\circ}\text{C}$ , and the daily minimum and maximum temperatures are  $-32^{\circ}\text{C}$  and  $33.5^{\circ}\text{C}$ , respectively. Three major rivers flow across the county, and three mountains lie from west to east, constituting approximately 94% of the total area. It has rich pasture resources, a prerequisite for the development of

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