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Temporal change in land use and its relationship to slope degree and soil type in a small catchment on the Loess Plateau of China

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Abstract

We sought to detect the temporal change (1958 – 1999) in land use patterns and its relationship to physical landscape parameters in a small catchment in the semi-arid hilly area of the Chinese Loess Plateau. Degree of slope and soil type were selected as stable discriminating parameters that might constrain land use. With the help of GIS and canonical correspondence analysis, the relationship between rural land use distribution or transformation and the selected physical parameters was examined. The land use had undergone a general shift from farmland to woodland or grassland. Canonical correspondence analyses (CCA) indicated that a relationship between land use and the selected physical parameters was evident, farmland coincided with favorable conditions of fertile soil and gentle slope, while grassland and woodland were associated with conditions of poorer soil and steep slope. In the more favorable conditions the main land use change process was the intensification of farming, while in the less favourable conditions it was the abandonment of farmland. A thorough understanding of the relationship between land use temporal or spatial patterns and landscape physical parameters in the Loess Plateau of China, like degree of slope and soil type, will enhance our capability to predict landscape dynamics and lead to more sound and effective land use management strategies.

Keywords: Land use pattern; Soil type; Degree of slope; Canonical correspondence analysis (CCA); Loess Plateau of China

1. Introduction

For centuries, humans have been altering the Earth's surface to produce food through agricultural activities. In most regions, these changes are thought to have been driven by the complex interaction of physiographic and socioeconomic factors (Forman, 1995; Zonneveld, 1995). Human activity is a major force in affecting spatial and temporal changes in land use, but the underlying physical structure of a landscape often constrains the use of land (Domon et al., 1993; Silbernagel et al., 1997; Verburg and Chen, 2000).

A thorough understanding of the patterns, the causes, and the social and ecological consequences of historical changes will enhance our capability to predict future landscapes and devise more effective landscape management strategies (Kienast, 1993). Although anthropogenic factors determine when and to what extent land use is modified at a certain location (Verburg and Chen, 2000), the modification and conversion of land cover and land use are driven by the interaction in space and time between biophysical and human dimensions (Turner et al., 1993; Pan et al., 1999). Few studies of land-use/land-cover change provide an integrated assessment of the driving forces (Reid et al., 2000). Most studies aim at understanding rural landscape dynamics in response to changes in socioeconomic forces (Vanacker et al., 2003; Krausmann et al., 2003; Habeil et al., 2003). Clearly, more data are needed to understand how stable physical attributes of landscape elements directly constrain land use pattern and determine land use change.

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The Chinese Loess Plateau, located in the middle reaches of the Yellow river basin, is the largest region of loess with perhaps the most serious soil erosion in the world (Fu et al., 2003). The most important explanation for soil erosion is low vegetation coverage as a result of unsuitable land use (Liu, 1999; Fu et al., 2000, 2004). Agriculture is the principal economic activity in the Loess Plateau. In order to effectively control soil erosion in the Loess Plateau, it is critical to adjust the agricultural landscape through the redesign of the land use pattern and composition (Fu and Chen, 2000). The Chinese government has paid increasing attention to control of soil erosion in the Loess Plateau. The small catchment scale was regarded as the basic unit to integrate soil erosion control with improvement in living conditions on farms in the northern Loess Plateau (Zhu and Tian, 1993). Adjusting the land use pattern so as to restore the deteriorated ecosystems and modify the local rural income structure was regarded as the main measures to control soil and water erosion and to improve poor farmers' living conditions in the Loess Plateau (Chen et al., 2001).

We selected the Zhifanggou catchment (about 8.27 km^2) in the semiarid hilly and gully area in northern Loess Plateau China as the case study area. The objectives of this study were (1) to quantify changes in land use from 1958 to 1999 in five periods, (2) to identify the influence of degree of slope and soil type on land use distribution and transformation and (3) to evaluate the method for analyzing the relationship between land use distribution or transformation and important physical attributes.

2. Materials and methods

2.1. Study area

Zhifanggou catchment is situated in An'sai county, Shaanxi province in the northern part of the Loess Plateau (Fig. 1). There are three villages in the small catchment, called Shiyaoxian, Washuta and Zhifanggou, with 552 habitants in total in 2002. The total area is about 8.27 km^2 at an elevation of 1010–1431 m and a gully density of 4.20~8.06 km km^{-2}. This region has a typical semi-arid continental climate with an average temperature of 8.8 °C (min. −23.6 °C and max. 36.8 °C) and an average annual precipitation of 549 mm. Rainfall shows high seasonal variability with about 61% falling between July and September. Within the study catchment, temporal and spatial variation in climatic factors such as temperature and precipitation are large. The degree of slope varies from 0° to 65°. The soils, developed on wind-accumulated loess parent material, are fertile but very susceptible to erosion by nature and characterized by intensive human activity and poor vegetation. There is significant spatial variation in degree of slope and soil conditions but their temporal variation is here assumed to be relatively small. Therefore, degree of slope and soil type were in this study selected landscape physical parameters to reveal their influence on land use distribution and transformation.

Due to long-term human activity, most natural vegetation has been destroyed. Land use types include cropland,

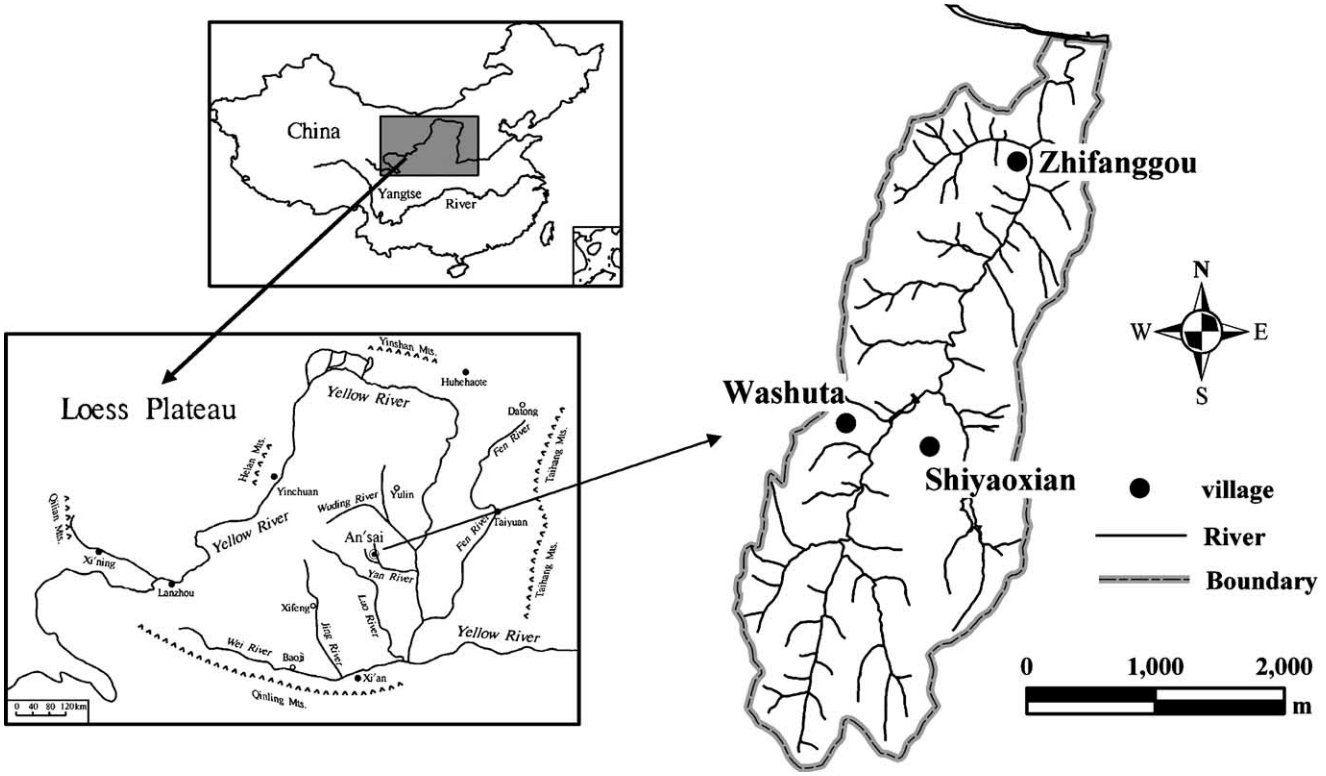

Fig. 1. Location and characteristics of Zhifanggou catchment.