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A methodology of characterizing status and trend of land changes in oases: A case study of Sangong River watershed, Xinjiang, China

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Abstract

Land change is often studied with Markov models to develop a probability transition matrix. The existing methods dependent on such matrixes cannot effectively characterize some important aspects associated with land change such as status, direction, trend and regional variations. This study presents mathematical models to quantify these elements, defining unbalanced, quasi-balanced and balanced status, one- and two-way transitions and the rising or falling trends. Using these models and remote-sensing imageries, the landscape was studied for a case area, the oasis of Sangong River in Xinjiang, Northwest China where typical arid conditions prevail. Land expansion and contraction among various land types and for the entire oasis were analyzed for the periods of 1978–1987, 1978–1998 and 1987–1998. The changes were closely related to a strong economic growth after the land-reform campaign and adoption of the market economy in China in the 1980s to early 1990s, a process not strictly Markovian that requires stationarity and randomness. Information on land-change status and trend is important for a better understanding of the underlying driving processes but also for land-use planning and decision-making.

Keywords: Land change; Status and trend; Markov models; Remote sensing; Oasis; Sangong River; Xinjiang; Northwest China

1. Introduction

Land change and its effects on ecological systems have received worldwide attention since the 1990s (Turner et al., 1993, 1995). Increased efforts have been made to understand the process, trend and driving forces of land change and the ecological consequences (Verburg et al., 1999a, b; Geist and Lambin, 2002; Irwin and Geoghegan, 2001; Lambin, 2002; Ojima et al., 2002; Parker et al., 2003; Gutman et al., 2004; Turner et al., 2004). Identifying the primary causes and estimating the processes and trends of land change are crucial for land-use planning, utilization of regional resources and management of the environment (Ojima et al., 2002; Turner, 2002; Velázquez et al., 2003).

Land change has been extensively studied for its processes and trends using probability transition matrixes developed from Markov models (Burnham, 1973; Bell, 1974; Turner, 1987, 1988; Muller and Middleton, 1994; Jenson and Cowen, 1997; Velázquez et al., 2003; Pontius et al., 2004). Such transition or cross-tabulation matrixes can be built simply by overlapping land-type maps of different time periods. This approach treats physical state changes as Markovian random processes that are conditional on the initial state only. Although this method can be used to quantify the transition-probability relations and describe effectively the process, the prediction of land change is questionable when major land changes were triggered by abrupt shifts in governmental administration and policy. This is because, under these causal conditions, assumptions for randomness and stationarity perquisite for Markov models to operate remain invalid (Wood et al., 1997).

Recently, a statistical method based on cross-tabulation matrixes was introduced with focus on the total change of land types as reflected by net change, land swap and gross gains and losses (Pontius et al., 2004). However, the statistical models or equations in this study are complicated and not easy to understand. Moreover, this method

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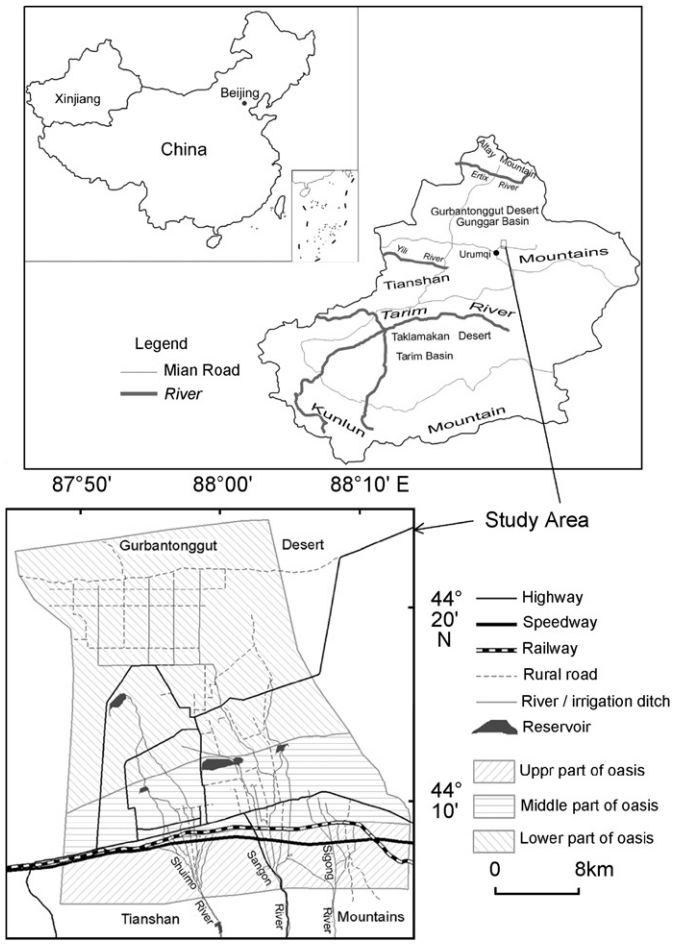

Fig. 1. Location of the study area. The upper, central and lower parts of the oasis of the Sangong River are outlined.

cannot be used to describe effectively some important aspects or elements associated with land change such as balanced or unbalanced status, one-way or two-way transitions and rising or falling trends. As such, improved methods are needed; in particular, where the land-change results from shifts in administration and policy.

Among land changes, a particular type is related to oases in desert environments. Oases, with a more productivity than the surrounding deserts, are the primary sites for human settlement because of the availability of fertile soil, fresh groundwater and surface runoff from the nearby mountains (Jia, 1996). Land change in oases has been a major concern for the Xinjiang province, Northwest China. Over the past 50 years, the local vegetation and soil have been changed or modified by large-scale land reclamation, irrigation and cultivation, as well as the application of fertilizers across this region (Fan, 1993; Wang and Cheng, 1998; Luo et al., 2003). For instance, some native plants are eliminated and replaced by exotic species. To protect the fragile ecosystem and maintain a sustainable development for the oases, it is utterly important to understand the current status and trend of the land change better land-use policies and management strategies can be developed.

This study tries to address these issues by examining the land change from 1978 to 1998 for the oasis of the lower Sangong River basin on the piedmont of northern Tian Shan mountains where land-use activities are strong (Fig. 1). The objectives of this study are to develop quantitative models for characterizing status, directions and trend of land change and to apply the models to a case area located in the Sangong River basin.

2. Study area and data

2.1. Study area

The Sangong River drains Tian Shan mountains and flows northward into the southern Junggar Basin in Xinjiang, with a total drainage area of 1670 km^2 (Fig. 1). The drainage basin consists of three physiographical units, Tian Shan mountains to the south, oasis in the middle and, to the north, the southern flank of the Gurbantonggut Desert. The oasis covers the piedmont of Tian Shan and the basin margin of the Junggar Basin with a size of about 942 km^2, sloping to the north with an elevation ranging from 700 to 465 m a.s.l (above sea level) (Fig. 1). Alluvial fans often containing a narrow, distal phreatic zone dominate the southern part of the oasis and, in the north, a flat, low-gradient alluvial plain occurs (Table 1).

Spatial variations in soil and vegetation are evident across the oasis. The upper alluvial fans where the main vadose zone is located consist of a gravelly to sandy desert soil, covered mostly by shrub *Petrosimonia sibirica* and *Seriphidium borotalense*. Major crops are corn and winter wheat. However, in the middle fans, the soil tends to become thicker and sandier and *Reaumuria soongorica* is the dominant plant. The distal fans, where the phreatic zone is located and shrub *Phragmites communis* becomes dominant, are often cultivated for agriculture because of the improved moisture conditions and presence of medium to fine-textured soil.

The alluvial plain has a fine-textured clayey soil. Because of the presence of a shallow groundwater and strong evaporation, vertical exchange between water and mineral salts at the ground surface is active, resulting in concentrations of Na, K and Ca in the soil. This area is dominated by non-zonal halophilous vegetation such as *Halocnenum strobilaceum, Kalidium foliatum, Tamarix chinensis* and *Nitraria sibirica*. Cotton and winter wheat are the main crops in this area.

Because of the prominent variations in groundwater, soil and vegetation, the study area can be divided into 3 sub-regions: the upper oasis, corresponding to the upper and middle alluvial fans, the central, covering the middle and distal fans, and the lower oasis, located on the alluvial plain (Fig. 1, Table 2). Their boundaries are roughly defined from south to north by the lower limit of the vadose zone and the overflowing zone of phreatic water on the fans.