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Analysis of spatio-temporal dynamic pattern and driving forces of urban land in China in 1990s using TM images and GIS

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China has witnessed fast urban growth in the recent decade. This study analyzes spatio-temporal characteristics of urban expansion in China using satellite images and regionalization methods. Landsat TM images at three time periods, 1990/1991, 1995/1996, and 1999/2000, are interpreted to get 1:100000 vector land use datasets. The study calculates the urban land percentage and urban land expansion index of every 1 km² cell throughout China. The study divides China into 27 urban regions to conceive dynamic patterns of urban land changes. Urban development was achieving momentum in the western region, expanding more noticeably than in the previous five years, and seeing an increased growth percentage. Land use dynamic changes reflect the strong impacts of economic growth environments and macro-urban development policies. The paper helps to distinguish the influences of newly market-oriented forces from traditional administrative controls on China's urban expansion.

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Introduction

Urbanization is perhaps one of the most important human activities, creating enormous impacts on the environment at the local, regional and global scales (Turner et al., 1990). Although urbanization in the form of land-cover (either built-up or impervious surfaces) occupies less than 2% of the earth's land surface, there is plentiful evidence that human disturbance due to urbanization has significantly altered the natural landscape (Grubler, 1994).

Recent institutional changes, marketization and globalization have combined to bring about new processes of rural–urban interaction, giving rise to new forms of human settlements in China (Ma, 2002; Pannell, 2002). The latest national population census conducted in 2000, the fifth of this kind conducted since 1949, revealed an accelerated rate of urbanization, characterized not only by its sheer scale but also by the rapidity of changes that have no parallel elsewhere in the world. China houses the world's largest population: 1.265 billion people of whom 456 million (36%) live in cities and towns (State Council of China Office of Population Census 2001, p. 6). China has more people living

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in cities and towns than any other country. The census clearly identified a pattern of accelerated urbanization. The urban population rose from 20% in 1982 to 36% in 2000, a net gain of 16% in less than two decades. This stands in sharp contrast to the pre-reform era, when the urban population showed a marginal increase of 7.1% over a 30 year period (Chan, 1994; Zhang and Zhao, 1998). Rapid urban growth was mainly attributed to migration from the countryside to cities and towns, the conversion from rural administrative units to city units, and the natural urban population increase. The driving force is economic development. For instance, during the same period of 1982–2000, the gross national product (GNP) grew at an average annual rate of 9.4% and gross domestic product (GDP) by 9.52% by the comparable price index (NSB, 1991, 2001).

China's urbanization level will reach 50% and the urban population will be 1.5×10^9 by the end of 2020, based on the prediction of the construction department of central government. Two significant demographic changes will continue. One is the expansion of current cities and towns, while the other is the conversion of villages and countryside into cities and towns. Based on current urban residential land ratio in 1999, urban land was 2.94×10^6 hm² and took up 15.12% of the total residential land (LRDC, 2000). Moreover, the residential land ratio will increase dramatically because housing conditions have been much improved in China in recent years and will continue to improve in the coming decades. Hence, rapid urban expansion will have great impacts on land-use and cover change (LUCC) in China.

Land-cover change has long been viewed as being continuous, but in fact it could be a disjunctive process during a period of rapid change. This type of disjunctive process is often triggered by a shock event, which can initiate a cascade of changes along the system (Lambin et al., 2001). The economic reform started in China since late 1970s has been a decisive stimulus for rapid land cover changes. The implementation of the national macro-scale urban growth control strategy has had the greatest impact on urban development during the period when China was in a transition from a centralized planning to a market-oriented economic system. There has been a tendency for cities to expand into prime agricultural areas (Ferguson and Khan, 1992). As noted, rapid urbanization and urban expansion have been witnessed in the last two decades (Cai and Ren, 1998). Furthermore, one of the main outcomes of China's land use modernization process is the formation of new spatio-temporal patterns of urban land change. It is therefore of practical significance to study land-use and land-cover change dynamics in China.

There have been numerous studies of global urban growth. A three epoch time series for urban growth

in Washington, DC area was studied to demonstrate the economic and demographic drivers (Masek et al., 2002). A Markov cellular automata model was developed to simulate the transformation of desert landscape by urbanization process in the Phoenix metropolitan region (Jenerette and Wu, 2001). Gradient analysis was combined with landscape metrics to quantify its spatial pattern (Luck and Wu, 2002; Wu et al., 2003). One project carried out in 1997 under the auspices of the China State Land Administration had monitored the dynamics of urban expansion in 100 municipalities of China between 1989/1992 and 1996/1997 (Ji et al., 2001). Seto had studied urban growth in the Pearl River Delta including Guangzhou, Shenzhen and Zhuhai cities between 1988 and 1996 using Landsat TM (2002). The indicator of agricultural land loss was illustrated to integrate quantity of land loss, spatial integrity of land development and quality of land (Li, 1998). However, these fall short of examining the national scale urban dynamic pattern.

In order to build the modern process of Chinese land-use dynamic change and to predict the land-use and land-cover change trend, the Chinese Academy of Sciences decided to build the earth surface dynamic spatio-temporal data desktop using satellite data based on national resources and environment data sets (Liu et al., 2002a). It built the land use datasets at three time periods—1990/1991, 1995/1996 and 1999/2000—using Landsat TM images.

This paper studies national spatio-temporal patterns of dynamic urban expansion in China in 1990s using these large datasets. The paper investigates the main characteristics of spatial arrangements and temporal changes of urban land expansion. The paper focuses on describing spatial patterns of urban land change dynamics, and identifying main factors that play direct roles in shaping spatial variations of urban development. The paper will start with an examination of the data sources and analysis procedures adopted in the study and finally discuss directions and needs for future research.

Data sources

Data acquisition

The 30-m spatial resolution of Landsat thematic mapper (TM) is sufficient to capture the characteristic scales of human development, and the spectral range of the instrument is able to distinguish urbanization from other types of landcover change (Masek et al., 2002). TM images in 1999/2000 were interpreted to obtain land-cover vector datasets. Obtaining images at near anniversary dates is considered important for change detection studies (Pilon et al., 1988; Quarmby and Cushnie, 1989). In addition to this requirement, the time at which the images were acquired was also considered critical. The best time

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