Spatial-Temporal Patterns of Urban Growth in Shanghai, China: Monitoring, Analysis, and Simulation

QIAN ZHANG

Academic Dissertation which, with due permission of the KTH Royal Institute of Technology, is submitted for public defence for the degree of Licentiate of Technology on Thursday the 21st January 2010, at 10:00 a.m. in Seminar Room 4055, Drottning Kristinas väg 30, 1tr, KTH, Stockholm.
Abstract

Supporting huge population, megacities are definitely the hot spots of production, consumption, and waste generation. Without careful investment and planning, megacities will be overwhelmed by burgeoning negative impacts on the environment, natural resources, and human health, as well as a host of social and economic issues. The unprecedented combination of economic and population growth since the Reform and Open Policy has led China into transition from a largely rural society to a predominantly urban one. Chinese cities, without question, have not escaped the danger of the series of problems during the rapid progress of urbanization. Therefore, monitoring the spatial-temporal patterns of urban sprawl and their impact on the environment is of critical importance for urban planning and sustainable development, especially in developing Chinese cities such as Shanghai.

To date, few studies have focused on the urban trajectories of Shanghai over the past 30 years from a remote sensing perspective. Most of the studies were concentrated on the technical issues of image processing and classification. Moreover, research on spatial metrics has focused on analyzing remote sensing classification results rather than on the use of interpreting, assessing, and verifying urban simulation results. Furthermore, many researches merely focused on baseline projection and very few studies took into consideration urban growth scenarios so far. As yet there have been no reported scenario simulations of future Shanghai growth with several land-use categories within urban areas.

The overall objective of this research is to investigate the integration of remote sensing, spatial metrics, and spatial-temporal models in the monitoring, analysis, and simulation of urban growth in Shanghai, China. The specific objectives are to: 1) monitor urban dynamics over time with multi-sensor remote sensing images; 2) quantify spatial-temporal properties of urban growth and representing the urban morphological structures by means of spatial metrics; and 3) simulate the geographic extent, patterns, and detailed catalogs of urban growth under different scenarios using Markov-Cellular Automata (Markov-CA) model to support decision making for a more sustainable Shanghai.

Through this study, the combined approach using remotely sensed data with change detection techniques, spatial metrics, and a scenarios-based simulation model proved to be effective to understand, represent, and predict the spatial-temporal dynamics of urban growth. In detail, the segmented-based hierarchy classification and visual interpretation were effective methods to extract urban and industrial land with high-resolution remotely sensed images. Direct change detection using variables derived from tasseled cap transformation was efficient for monitoring impervious surface sprawl. Spatial metrics is a quick and executable way to assessing the impact of urban sprawl.
on landscape dynamic. Markov-CA model is a useful tool to simulate the scenarios of future urban developments and therefore provides the policy options for sustainable urban planning.

The research results of urban trajectories and impervious surface sprawl showed that Shanghai experienced high-speed urban sprawl and the rate of urban expansion, however, was not homogeneous spatially and temporally. The general annual urban expansion speed was $34.8 \text{ km}^2$ per year; nevertheless, it reached $80.2 \text{ km}^2$ per year recent six years from 2001 to 2007, while it touched the bottom speed around $14.3 \text{ km}^2$ per year during 1979-1989. The expanded area in the Puxi region was 5.23 times of its original area while that of Pudong region was 19.94 times of its original area during 1979-2007. The research results of landscape analysis demonstrated that greenbelt becomes fractured while infrastructural and commercial area is more and more aggregated in the central Shanghai area, and satellite images such as SPOT Pan, XS and Landsat TM with 10-30 meter resolution are sufficient for the landscape dynamic research in central Shanghai area. The results of scenarios-based simulation indicated that built-up areas in Shanghai will increase significantly in 2025 and Shanghai will experience less urban sprawl and retain a better environment in 2025 under service-oriented center (SOC) than under baseline (NS) or manufacturing-dominant center (MDC) scenario. If favorable policy for MDC scenario is adopted, however, there will be a lot of manufacturing industries gathering in Shanghai and more agricultural lands will be encroached.

The present research focused on the analysis of physical and morphological aspects of urban growth. Urban land-use dynamics are, however, intrinsically linked with socio-economic, political, or demographic drivers. Trying to fill in the missing link between traditional urban geography and urban remote sensing & urban simulation and to improve understanding of the interactions between human and natural aspects in the urban socio-ecosystem is the major focus in the next phase of the Ph.D. research.

Keywords: Urban growth, Spatial-temporal pattern, Remote sensing, Spatial metrics, Scenarios-based simulation, Shanghai

**Key Words**

urban growth, spatial-temporal pattern, remote sensing, spatial metrics, scenarios-based simulation, Shanghai