Ecological Indicators 20 (2012) 82–91

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Simulating urban growth processes incorporating a potential model with spatial metrics

Fanhua Kong[a,*], Haiwei Yin[b], Nobukazu Nakagoshi[c], Philip James[d]

[a] International Institute for Earth System Science (ESSI), Nanjing University, No. 22, Hankou Road, 210093 Nanjing, China
[b] Department of Urban Planning and Design, Nanjing University, No. 22, Hankou Road, 210093 Nanjing, China
[c] Graduate School for International Development and Cooperation, Hiroshima University, Kagamiyama 1-5-1, Higashi-Hiroshima 739-8529, Japan
[d] School of Environment and Life Sciences, University of Salford, Salford, Greater Manchester M5 4WT, UK

ARTICLE INFO

Article history:
Received 31 July 2011
Received in revised form 26 January 2012
Accepted 2 February 2012

Keywords:
Urban growth
Moving window method
Potential model
Landscape metrics
Matrix analysis
GIS

ABSTRACT

Urbanization is one phenomena that drives land use pattern change. Persistent rapid urbanization is associated with depletion of natural resources and worsening conditions in the urban environment. Monitoring urban development is, therefore, an absolute necessity in order to assure sustainable cities in the future. The main objective of this paper is to develop and apply an urban growth potential model incorporating spatial metrics. The model has been tested in Jinan City, China. Firstly, two satellite images (1989 and 2004 SPOT) were used to extract the land-cover. A general land use spatial pattern analysis, based on landscape metrics and a transformation matrix analysis, was conducted. Secondly, a moving window method was used to identify and capture the urbanization process through the PLAND landscape metric. The remote satellite data have been further processed: first to produce an initial state of the land-cover surface, and second to perform a time-series analysis and to assess the potential accuracy of the model application. In the second step, the calibrated model was used to predict the location of the urban growth over 16 years (2004–2020). The results indicated there will be a significant land use change until 2020. However, the spatial distribution of the potential growth areas is not homogenous. The study has confirmed the usefulness of a growth potential model incorporating the moving window method to predict urban growth trends and examining the impacts of urban development on natural resources. The results can provide decision support documents for urban planners and stakeholders with spatially explicit information for future planning and monitoring plans.

1. Introduction

It is expected that about 60% of the world's population will live in urban areas by 2030 (United Nations Department of Economic and Social Affairs/Population Division, 2003). Although urban areas make up a small proportion of the earth land surface area (Grübler, 1994) they cannot be ignored as urban growth causes very large changes in environmental conditions – more so than other land use changes (Heilig, 1994; Lambin et al., 2001).

Analyzing the urban development process and then using appropriate management strategies that aid sustainable urban development is one of the most important ways to address the environment problems arising from urban growth (Fang et al., 2005; Jaeger et al., 2010). Monitoring urban change implies taking account of two key points: the extent and location of current and future changes. Accordingly, the description and analysis of spatial distributions and structural characteristics of urban land use, as well as modeling and predicting their spatio-temporal change, have become important issues (Wegener, 1994; Klostermann, 1999; Deng et al., 2009). Recent developments include the integration of remote sensing, GIS and other geospatial techniques (Batty, 1992; Longley, 2002), and advances in disciplines such as Landscape Ecology have helped in quantifying, monitoring, modeling and subsequently predicting the urban development (Sudhira et al., 2004; Herold et al., 2005; Deng et al., 2009; Pham et al., 2011).

Remotely sensed data provide a unique view on spatial and temporal urban change patterns and thus could be used to improve understanding and modeling of urban development and change processes (Meaille and Wald, 1990; Wu, 1998; Batty and Howes, 2001; Herold et al., 2003), and, consequently, they have been used increasingly to map urban development (Stuckens et al., 2000; Stefanov et al., 2001; McCauley and Goetz, 2004). Developments within Landscape Ecology provide an important theoretical basis for urban land use change research. Landscape Ecology is the study

* Corresponding author. Tel.: +86 13 851550561; fax: +86 25 83592288.
E-mail addresses: fanhuakong@163.com, fanhua_kong@yahoo.com (F. Kong).

1470-160X/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecolind.2012.02.003

of spatial and temporal patterns on the land and their consequences to organisms, populations, communities, and ecosystems (Giles and Train, 1999; Palmer, 2004; Li et al., 2005; Mander and Uuemaa, 2010), and it can be used to understand land-use patterns (e.g. Riitters and Wickham, 1995; Jaeger et al., 2010; Pham et al., 2011). Landscape Ecology-based spatial landscape metrics are useful tools in mapping and quantifying spatial land cover characteristics. Landscape metrics were developed in the late 1980s (Mandelbrot, 1983; Herold et al., 2005; Liu et al., 2010) and are normally used in ecological investigations (Li et al., 2005; Peng et al., 2010). However, they are now being extended to enhance understanding of the urban forms. Computation of these indices will help in understanding the process of urbanization at a landscape level (Sudhira et al., 2004; Peng et al., 2010).

In China, significant economic and spatial transformation has taken place since the late 1970s; coinciding with the time when China began to abandon the self-reliance economy and adopted more reforming and open policies (Yang, 2004). In the 30 years following 1978, China's urban population increased dramatically from 170 million to 607 million, that is to say from 18% to 46% of the total population (China Statistics Bureau, 2009). The speed of change and the scope of urban spatial reconfiguration are globally unprecedented. Almost all Chinese cities, big and small, have experienced fundamental spatial change in the last three decades, and there has been a considerable expansion of the built-up areas from 0.6×10^4 km^2 in 1979 to more than 2.8×10^4 km^2 in 2007 (China Statistics Bureau, 2009). Associated with this growth are worsening conditions of crowding, deteriorating urban environments, and fragmentizing or loss of natural resources (Thapa and Murayama, 2009). Analyzing and modeling urban dynamic spatial change process are urgently required as they will provide insights for assessing urban growth and future development. Whilst most of the related research in China has focused on the large cities like Beijing, Shanghai and Shenzhen (Li and Yeh, 2004; Xiao et al., 2006; He et al., 2008; Han et al., 2009) less attention has been paid on the middle size cities, like Jinan, which are more typical of development across the country and in other expanding economies.

In this paper the authors aim to: (1) capture the extent and location of land use change in Jinan City from 1989 to 2004 based on landscape metrics and matrix analysis; (2) simulate the urban growth potential to 2020 with the urban growth potential model; and (3) map and analyze the areas with high probabilities or potential for urban growth and find their spatial distribution characteristics. The results could be used in decision support systems enabling planner to get a first idea of the urban development trends.

2. Study area

Jinan is located within Shandong Province, to the north of Taishan and south of the Yellow River at latitude 36°32′–36°51′N longitude 116°49′–117°14′E. Jinan has a warm-temperate, semi-humid, continental monsoon climate, and well-defined seasons. The mean annual temperature is 14 °C and the mean precipitation is 650–700 mm (Jinan Landscape Bureau, 2001).

In the past several decades, Jinan has experienced rapid economic growth. The gross domestic product (GDP) in Jinan increased

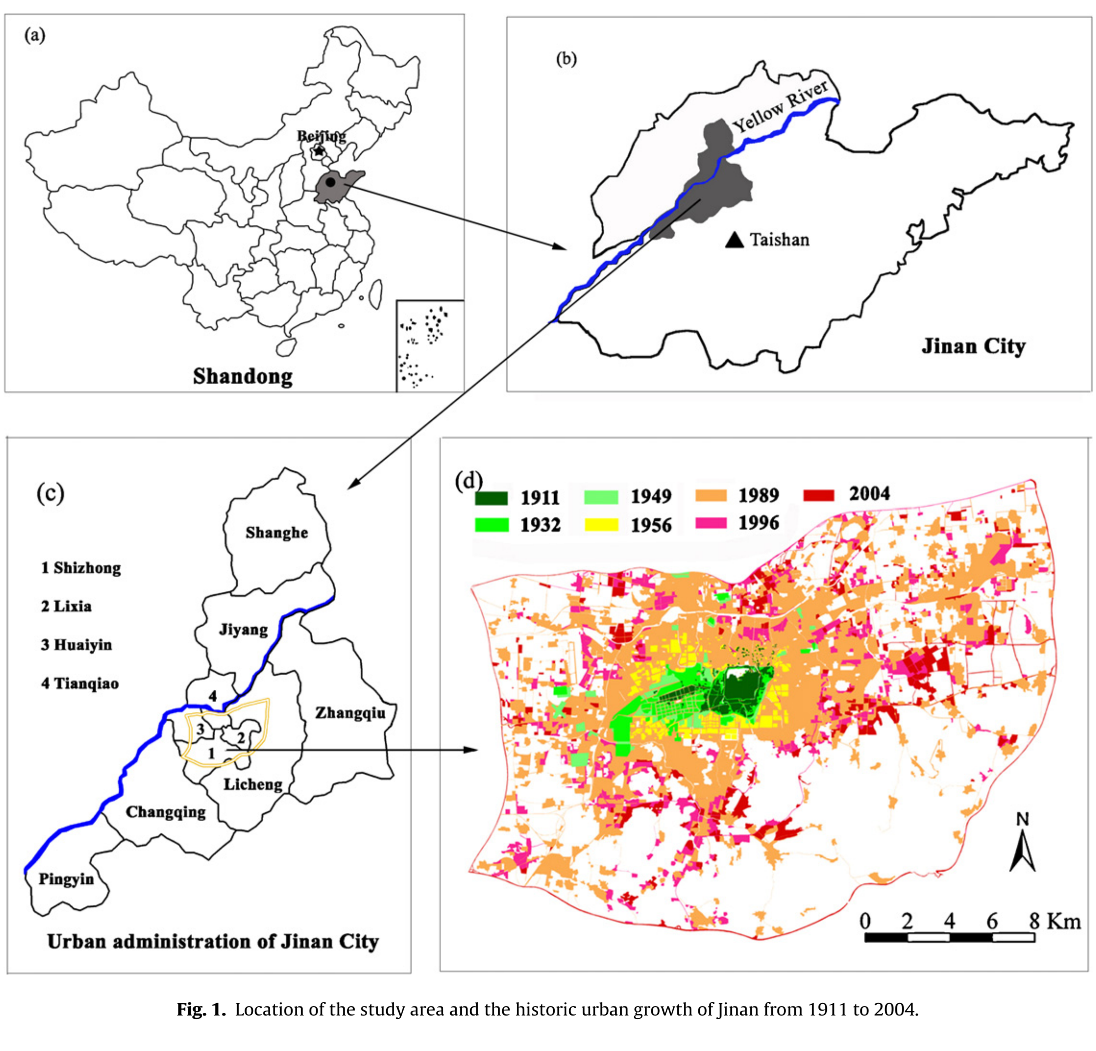

Fig. 1. Location of the study area and the historic urban growth of Jinan from 1911 to 2004.