Applied Geography 30 (2010) 96–111

Contents lists available at ScienceDirect

Applied Geography

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

Quantifying the degree-of-freedom, degree-of-sprawl, and degree-of-goodness of urban growth from remote sensing data

B. Bhatta [a,*], S. Saraswati [b], D. Bandyopadhyay [b]

[a] Computer Aided Design Centre, Dept. of Comp. Sc. & Engg., Jadavpur University, Kolkata 700 032, India
[b] Dept. of Construction Engineering, Jadavpur University, Kolkata 700 098, India

Keywords:
Remote sensing
GIS
Urban growth
Urban sprawl
Degree-of-goodness
Kolkata
Howrah

A B S T R A C T

Urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. Analysis of urban growth by using the historical and present data is an essentially performed operation in the urban geographic studies and for future planning. Urban growth can be mapped, measured and modelled by using remote sensing data and GIS techniques along with several statistical measures. In this study three temporal satellite images of 15 years interval (1975, 1990 and 2005) have been classified to determine the urban extent and growth of Kolkata-Howrah (West Bengal, India) in eight different directions within a circular region. Pearson's chi-square test and Shannon's entropy method have been applied to calculate the degree-of-freedom and degree-of-sprawl towards the analysis of urban growth. A new measure, degree-of-goodness, has also been proposed for the analysis of urban growth. The result shows that the city of Kolkata-Howrah has a high degree-of-freedom, high sprawl, and a negative goodness in urban growth. Apart from the derived results, this study also shows the potentials of remote sensing data and effectiveness of demonstrated/proposed models in urban geographic studies.

Introduction

Urban growth is one of the processes of *urban development*. The occurrence of urban development is so general, and its implications are so wide, that it is possible to view much of recent social and economic history in terms of the attempts to cope with its varying consequences. The rise of great cities and their growing spatial influence initiated a change from largely rural to predominantly urban places and patterns of living that has affected most countries over the last two centuries. Today, not only do large numbers of people live in or immediately adjacent to towns and cities, but whole segments of the population are completely dominated by urban values, expectations, and life styles. From its origins as a locus of non-agricultural employment, the city has become the major social, cultural and intellectual stimulus in modern urban society (Clark, 1982).

Urban development is the process of emergence of the world dominated by cities and by urban values. It is important to draw a clear distinction between the two main processes of urban development—*urban growth* and *urbanization* (Clark, 1982). Urban growth is a spatial and demographic process and refers to the increased importance of towns and cities as a concentration of population within a particular economy and society. It occurs when the population distribution changes from being largely hamlet and village based to being predominantly town and city dwelling. Urbanization, on the other hand, is aspatial and social process which refers to the changes of behaviour and social relationships that occur in social dimensions

* Corresponding author. Tel.: +91 33 2435 7847 (R), +91 33 2414 6844 (O).
E-mail address: basu_bhatta@rediffmail.com (B. Bhatta).

0143-6228/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.apgeog.2009.08.001

as a result of people living in towns and cities. Essentially, it refers to the complex change of life styles which follow from the impact of cities on society.

The spatial configuration and the dynamics of urban growth are important topics of analysis in the contemporary urban studies. Several studies have addressed these issues with or without the consideration of demographic process and urbanization which have dealt with diverse range of themes (e.g., Acioly & Davidson, 1996; Belkina, 2007; Geymen & Baz, 2008; Hedblom & Soderstrom, 2008; Martinuzzi, Gould, & Gonzalez, 2007; Páez & Scott, 2004; Puliafito, 2007; Wang, Zhu, Wang, & Shi, 2003; Yanos, 2007; Zhang & Atkinson, 2008; Zhu, Xu, Jiang, Li, & Fan, 2006). The review of literature found that the growth in urban[1] land-cover generally has several implications, such as, higher economic production and opportunities for the underemployed, destruction of environmental and ecological structure, environmental pollutions, loss of surface water bodies and groundwater prospects, increase in temperature, informal settlements, loss of farmland and woodland, and scarcity of food (Barnes, Morgan, Roberge, & Lowe, 2001; Benfield, Raimi, & Chen, 1999; Grimm, Grove, Pickett, & Redman, 2000; Hedblom & Soderstrom, 2008; Heimlich & Anderson, 2001; Kirtland et al., 1994; Kunstler, 1994; Lassila, 1999; Macie & Moll, 1989; O'Connor, Overmars, & Ralston, 1990; Wang et al., 2003; Weng, Liu, & Lu, 2007).

The review of literature also found that the urban growth has aroused wide social focus because in many instances this growth is uncontrolled and dispersed (referred to as sprawl) which may impede regional sustainable development. Rapid urban growth in the world is quite alarming, especially, in developing countries like India (Angel, Sheppard, & Civco, 2005; Kumar, Pathan, & Bhanderi, 2007). Therefore, the importance of conducting researches on urban growth has been strongly felt throughout the world; and related studies have come out consequently which mainly cover the *pattern* (Forman, 1995; Galster, Hanson, Wolman, Coleman, & Freihage, 2001; Heimlich & Anderson, 2001; Wasserman, 2000; Wilson, Hurd, Civco, Prisloe, & Arnold, 2003), the *process* (Davis, 1965; Ewing, 1997; Galster et al., 2001; Harvey & Clark, 1965; Herold, Hemphill, Dietzel, & Clarke, 2005), the *cause and consequence* (Barnes et al., 2001; Benfield et al., 1999; Brueckner, 2000; Buiton, 1994; Ewing, 1997; Grimm et al., 2000; Harvey & Clark, 1965; Hedblom & Soderstrom, 2008; Heimlich & Anderson, 2001; Kirtland et al., 1994; Kunstler, 1994; Lassila, 1999; MacDonald & Rudel, 2005; Macie & Moll, 1989; McArthur & Wilson, 1967; Mitchell, 2001; O'Connor et al., 1990; Pedersen, Smith, & Adler, 1999; Stoel, 1999; Wang et al., 2003; Weng et al., 2007; Wilson et al., 2003), and *countermeasures* (Alterman, 1997; Anderson, 1999; Asif & Shachar, 1999; Bhatta, 2009c; Brueckner, 2000; Burby, Nelson, Parker, & Handmer, 2001; Coughlin, 1991; DeGrove & Deborah, 1992; Frenkel, 2004; Gatrell & Jensen, 2002; Hollis & Fulton, 2002; Juergensmeyer, 1984, 1985; Longley, Batty, Shepherd, & Sadler, 1992; Nelson & Moore, 1993; Schiffman, 1999; Wassmer, 2002) as well.

However, this study deals only with the pattern and process of urban growth. Urban growth should be analysed both as a *pattern* of urban land-use—i.e., a spatial configuration of a metropolitan area in a temporal instant—and as a *process*, namely as the change in the spatial structure of cities over time. Urban growth as a pattern or a process is to be distinguished from the causes that bring such a pattern about, or from the consequences of such patterns. If the urban growth is considered as a pattern it is a static phenomenon and as a process it is a dynamic phenomenon. Analysis of urban growth, as a pattern or process, is an essentially performed operation by the city planners and administrators, proponents, and other stakeholders. However, stakeholders are generally interested in the future pattern of urban land-cover rather than the past or present in view of their investment goals; but the city administrators/planners and proponents require analysing the pattern of urban growth for the past and present in order to prepare for the future.

Urban growth, as a pattern, although helps us to understand the spatial distribution but as a static phenomenon. In fact, areas that can be identified as sprawl for a specific time are typically part of a dynamic urban scene (Ewing, 1997; Harvey & Clark, 1965). Some parts of the city may pass through a sprawled stage before eventually thickening so that they can no longer be identified as sprawl (Herold et al., 2005). Therefore, the urban growth analysis should take into account both the pattern and as well as the process. Analysis of urban growth, as a pattern and process, helps us to understand how an urban landscape is changing with time. This understanding includes (1) the rate of urban growth, (2) the spatial configuration of growth, (3) whether there is any discrepancy in the observed and expected growth, (4) whether there is any spatial or temporal disparity in growth, and (5) whether the growth is sprawling or not. Analysis of urban growth can be performed for the past, present, and for the future as well. However, the case of past and present is different than the future; because the former is based on empirical evidences whereas the later is based on simulations. However, the simulation is obviously dependent on the past and present evidences.

In the recent years, remote sensing data and geographic information system (GIS) techniques are widely used for mapping (to understand the pattern), monitoring (to understand the process), and modelling (to simulate) the urban growth, land-use, and sprawl. The physical expressions and patterns of urban growth and sprawl on landscapes can be detected, mapped, and analysed by using remote sensing data and GIS techniques (Angel et al., 2005; Barnes et al., 2001; Kumar et al., 2007; Pathan, Jothimani, Pendharkar, & Kumar, 1989; Pathan, Shukla, Patel, & Mehta, 1991). The decision support systems within the GIS can evaluate remote sensing and other geospatial datasets by using multi-agent evaluation (Axtell & Epstein, 1994; Parker, Manson, Janssen, Hoffmann, & Deadman, 2003) which can also predict the possibilities in the subsequent years using the current and historical data. In the last few decades, these techniques have successfully been implemented to detect and model the urban growth dynamics.

[1] The word *urban*, in this paper, has been used synonymously with developed land, i.e., land covered by built-up or any other impervious surfaces like roads, runways etc. This land-cover class includes residential as well as commercial and industrial land uses that result in a developed or built landscape.