Habitat International 35 (2011) 521–528

Contents lists available at ScienceDirect

Habitat International

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

Urban sprawl pattern and land-use change detection in Yazd, Iran

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Keywords:
Urban sprawl
Satellite images
Land-use change
Yazd
Iran

A B S T R A C T

Urban sprawl has become a remarkable characteristic of urban development worldwide in the last decades. However, trajectories and rhythms of sprawl may vary in important ways according to specific geographical and historical characteristics, and these differences need to be contrasted with specific case studies especially for the booming urbanization of the Global South. The purpose of this paper is to study urban growth in the city of Yazd, Iran. Urban growth and other land uses were calculated through treated satellite images for four periods: 1975, 1987, 2000 and 2009. Results reveal that from 1975 to 2009, the urbanized area increased from 1843 ha to 13,802 ha; that is a rate close to three times the population growth observed for the same period. The Yazd case is interesting for several reasons: first, it is a case of very fast urban growth even for a developing country; second, it illustrates how the fastest rates of urban sprawl may correspond to middle size cities rather than large centers. Third, it portrays a land substitution process in which agricultural land is not the primary provider of urban land which is relatively rare in urban contexts, and fourth, it also illustrate how sprawl may also hide important internal land uses such as the presence of agricultural plots within urban boundaries.

Introduction

According to United Nations estimates, the population living in urban areas exceeded 50% of the world total in 2006 and will approach 60% in 2020. Most if not virtually all this growth is taking place in developing countries. While the explosive urban growth in the Global South is a well known phenomenon, the specific trajectories and forms of this growth are still relatively unknown. In most of the world, urban growth appears to have taken the form of disperse or sprawled patterns but case studies are needed to ascertain whether the "American model" of urban sprawl (Leichenko & Solecki, 2005) is dominant or, rather, it represents just a version of a much wider process.

Urban sprawl is a pattern of land use exhibiting low levels of eight distinct dimensions: density, continuity, concentration, clustering, centrality, nuclearity, mixed uses and proximity. Density is the average number of residential units per square mile of developable land in an urban area. Continuity is the degree to which developable land has been built in close proximity to the already existing urban fabric. Concentration is the degree to which development is located disproportionately in relatively few square miles of the total urban area rather than spread evenly. Clustering is the degree to which development has been tightly bunched to minimize the amount of land in each mile of developable land occupied by residential or nonresidential uses. Centrality is the degree to which residential or nonresidential development (or both) is located close to the central business (CBD) of an urban area. Nuclearity is the extent to which an urban area is characterized by a mononuclear (as opposed to a polynuclear) pattern of development. Mixed uses means the degree to which two different land uses commonly exist within the same small area. Finally, proximity is the degree to which different land uses are close to each other across an urban area (Glaster et al., 2001).

Because of these characteristics, urban sprawl is said to represent a threat for urban sustainable development since it implies an increase in the consumption of land, water, energy and other resources as well as of pollutants and waste. The environmental impacts of urban sprawl have raised concerns among planners and have stimulated other models of urban expansion such as "smart growth" (Gabriel, Faria, & Moglen, 2006; Litman, 2007, Turner, 2007) which attempt to reverse the low values of the eight dimensions stated above.

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doi:10.1016/j.habitatint.2011.02.004

Since World-War II urban sprawl has been an important feature of the urbanization process in certain developed countries such as the USA, Australia, Canada, and some European countries (Gill, 2008). Currently, urban sprawl is expanding to Southern Europe (Catalán, Saurí, & Serra, 2008), and also to a number of developing countries such as China (Cheng & Masser, 2003, Zhang, 2000), India (Jothimani, 1997; Lata, Sankar Rao, Krishna Prasad, Badrinath, & Raghavaswamy, 2001), and Turkey (Onur, Maktav, Sari, & Sonmez, 2009), among others.

Studies on urban sprawl have for the most part focused on large cities and metropolitan areas. However, middle sized and small urban areas may be actually those experiencing the highest rates of urban growth. For instance, Weng (2001), in a paper on the Zhujiang Delta in China, concluded that the largest urban expansion in this area occurred in Dongguan, Baoan, Nanhui and Zhuhai, all of them relatively small cities located in the Eastern part of delta. In contrast, older and larger cities, such as Guangzhou and Foshan, did not show a parallel increase in urban land. Jat, Garg, and Khare (2008) revealed that the growth in urban land of Ajmer City, a medium sized city situated in Rajasthan State of India, over a period of 25 years, tripled population growth with an increase of the urban area from 488 ha in 1997 to 1259 ha in 2002 (Jat et al., 2008). Also in India, Sudhira, Ramachandra, and Jagadish (2004), for a city with less than 0.5 million people, reported a population increase of 54% between 1972 and 1999, and an increase of urban area of 146% during the same period, that is, nearly three times the rate of population growth. The sprawl of urban land intermediate and small size cities continues in the developed world as in Santa Barbara, California (Herold, Goldstein, & Clarke, 2003), or in several Swiss municipalities (Gennaio, Hersperger, & Burgi, 2009), among many other examples.

While urban sprawl may be a process equally shared by developed and developing countries, specific causes and characteristics differ considerably. In the developed world, for instance, causes for urban sprawl range from consumer preferences to new strategies of capital accumulation in cities through real estate development (Muñiz, Calatayud, & García, 2007). However, the study of the causes behind urban sprawl remains less explored in the developing world. More examples of how this process unfolds in specific areas are needed to explore trends, causes and consequences that enrich our understanding of the urbanization process in areas where this process is more intense.

In this paper the case of the city of Yazd, is presented which is located in central Iran. Both Yazd and Iran as a whole are interesting and relevant cases of explosive urban growth. According to the first Iranian census, in 1956, the number of Iranian cities was 199 and the proportion of urban population was 31% of the total. In 2006, the number of cities had increased to 1012 and the proportion of urban population exceeded 70% of the total (Farhoudi, Zanganeh Shahraki, & Saed Moucheshi, 2009; Iranian Statistic Center, 2009). Urban population in Iran will reach 80% in 2020 according to the United Nations. Large urban centers such as Tehran (Zanganeh Shahraki, 2007), Mashhad (Hosseini, 2008) and Isfahan (Ghiumi Mohammadi, 2001) are experiencing transitional urban growth processes form compact to dispersed forms and sprawling rapidly Middle size and even small cities tend to sprawl as well perhaps at a greater pace. The city of Yazd is one of these medium sized cities undergoing rapid physical growth and change of land covers and uses. Since the definition of cities and urban hierarchies vary among countries, in this paper we use the Iranian urban hierarchy on the basis of population size. According to the definition of the Ministry of Housing and Urban Development (2008) and the Iranian Statistic Center (2009), cities in Iran are divided into six categories: rural–urban cities (population less than 25,000); small cities (population between 25,000 and 100,000); medium cities (population between 100,000 and 500,000); large cities (population between 500,000 and 1,000,000); metropolis (population between 1 million and 5 million); and, finally, megalopolis (population more than 5 million). Therefore, Yazd can be considered as a medium sized city. The recent urban history of Yazd encapsulates many of the dimensions mentioned at the beginning of the paper. Yet it also presents some distinctive features that offer interesting insights into the nature of urban growth in small and medium sized cities of the developing world.

Trends in urban expansion are examined here through the use of satellite images. Remote sensing is cost effective and technologically reliable, and is therefore, increasingly used for the analysis of urban sprawl (Haack & Rafter, 2006; Yang & Liu, 2005). In addition, remote sensing techniques have advantages in characterizing the spatiotemporal trends of urban sprawl using multi-stage images and providing a basis for projecting future urbanization processes. The use of satellite images will assist us in identifying the spatial and temporal patterns of urban land expansion from the urban core, and in detecting land-use change in urban fringes especially in what concerns the relation between urban and agricultural land uses. To address these objectives, multi-stage remote sensing images, geographic information systems and some secondary data from urban organizations will be deployed. The paper is organized as follows. First, our case study will be presented. This is followed by a section about materials and methods used to generate data through different satellite images. In the third section, population and urban growth variables were correlated. The fourth section consists in the presentation and discussion of more specific land transformation processes. Finally, some concluding comments, regarding the possible significance of Yazd for the understanding of urban sprawl in the context of the developing world are also included.

Study area

The city of Yazd, one of the more ancient cities of Iran, is the capital of the Yazd province, (Fig. 1). Yazd is located in a desert environment with an annual precipitation of 50–60 mm. There is no surface water and the city has historically relied on groundwater through the system of *qanat* (a system of connected underground wells). This term derives from an ancient semitic word meaning “to dig” and describes an underground water channel consisting of vertical shafts connected at their bottom with a sub-horizontal tunnel. The most important economic activities in Yazd are light industries (textiles, foodstuffs, and paper and furniture) occupying about 42% of the active population, and tourism which benefits from the desert architecture and the historical heritage of the city. Both activities alongside with the administrative functions derived from the condition of province capital serve as a factor of attraction for many immigrants not only from the province of Yazd but also from all Iran. Therefore, the city has experienced very rapid growth to the point that, among the Iranian cities with a population bigger than 100,000 inhabitants, Yazd has the largest growth in urban land development.

Materials and methods

Land cover and land-use change (LUC) recognition provides an essential input for environmental analysis, planning, and management. Nevertheless, land use/cover detection is not an easy task because of several uncertainties. Comparative analyses using classifications produced independently from different dates are called map-to-map comparisons or post-classification comparisons. In this case, two problematic issues appear. First, there may be locational inaccuracy due to the misregistration of polygon boundaries.