Beijing Urbanization in the Past 18 Years

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Abstract

Urbanization is a newly emerged problem in developing countries worldwide in nowadays. It has caused many ecological and environmental problems, which make it necessary to describe the process of urbanization to deal with these problems. Beijing, the capital city of China, also experienced a rapid urbanization in the past two decades since the reform and opening up policy launched by the central government in 1980's. Based on the remotely sensed data of Beijing at the years of 1984, 1991, 1994, 1997, 1999, and 2002, GIS and Fragstats analysis showed that the landscape metrics indicated a fragmentation of the city during the process of urbanization at both landscape and urban type levels. Transect sampling on the images and urbanization rate analysis showed that the Beijing expansion was different in directions in the past 18 years, which can be described as a West-East direction enlargement in 1980's, a North-South direction enlargement in 1990's, and a Northeastern and Southeastern enlargement in 2000's. The main driving forces of the urban sprawl were population and economy booming and the resulting infrastructural and housing construction, environmental protection policy, and the limitation of regional topography. The case of Beijing gives an example of urbanization study to other developing countries, and will be beneficial to a better understanding on the mechanisms of urbanization quantitatively.

Key Words: driving forces, landscape dynamics, landscape pattern analysis

1. Introduction

Urbanization is a pervasive and rapidly growing form of land use change in nowadays worldwide, which is a newly emerged phenomenon in particular in developing countries (Zipperer and Pickett, 2001). There are many glossaries relevant to urbanization: urban sprawl, suburbanization, counter-urbanization, urban fringe, edge cities and exurbs.

Although many factors are effective, two main forces drive the urbanization process: population and economy. It is well known that cities are essential because they serve as centers of education, culture and research, trade and commerce, and government (Zipperer and Pickett, 2001). Urban population increased very quickly, and most of population growth will occur in developing nations (Zipperer and Pickett, 2001). By 1985, 41% of the world's population was urban, and it is estimated that 60.1% of the global population will be urban by 2025 (UN Population Division, 1997). Consequently, cities are becoming increasingly dependent on national and international markets for food and other resources as the result of urbanization (Paul and Meyer, 2001). Although the overall land area covered by urban growth remains small (2% of earth's land surface), its ecological footprint can be large (Folke et al. 1997). For example, it is estimated that urban centers produce more than 78% of global greenhouse gases (Grimm et al. 2000) and that some cities in the Baltic region claim their ecosystems support areas 500 to 1,000 times their size.

The rapid population growth and fast economy development of cities have created many infrastructural and social problems, as well as some ecological and environmental problems (Zipperer and Pickett, 2001). Urban areas significantly affect the atmosphere by adding gases to it and changing the concentration of gases present in the environment. The human affected concentration of trace gases can significantly influence climate, precipitation pH, humidity and solar radiation. Those of particular importance include carbon dioxide (CO_2), nonmethane hydrocarbons (NMHC), sulfur (SO_x), and nitrogen (NO_x) oxides. Temperatures in cities tend to be higher than in rural areas, a phenomenon called the urban heat island effect. Ambient temperatures in cities can increase by 3 to 6.8℃ over rural temperatures just after sunset. As an area urbanized, the percentage of area in impervious surfaces increases. Impervious surfaces influence the hydrological cycle by decreasing the amount of evaporation, increasing the amount of surface flow, and reducing the amount of infiltration. In a typical nonurban area, 40% of water is evaporated, 10% moves as surface flows, and 50% infiltrates into the ground. In a typical urban area, 25% is evaporated, 43% moves as storm runoff and surface flows, and only 32% infiltrates into the ground. The decrease in infiltration lowers the groundwater table and reduces base flow to streams as well as aquifer recharge. Storm runoff is often toxic to aquatic life. As water flows across impervious surfaces, it picks up contaminants and chemicals such as salts, oil, antifreeze and pet waste. These contaminants and chemicals pollute bodies of water receiving the runoff. Urbanization could also fragment forests and cause soil properties change and pollution (Berling-Wolff and Wu, 2004). Urban growth affects ecological habitats when urban areas expand into the surrounding natural areas, diminishing them in size or resulting in habitat fragmentation, as well as generating damaging effects through such sources as pollution and human use (Landis, et al. 1998). The study of urban systems must be considered integral to the study of landscapes, and urban processes must be studied in order to understand their influences and predict their impact on surrounding ecosystems (McDonnell and Pickett, 1993; Foresman et al. 1997).

Knowing that the process of urbanization is the necessary information for environmental management

and sustainable development of cities, it is significant to describe the temporal dynamics for predicting its future change, although it is a difficult task as many factors influence the process (Heilig, 1994). In history, urban expansion is regarded as a common physical diffusion process and then the known process is used to build a simulation model for urban expansion to examine the use of land resources under various scenarios (Li et al. 2003). Many approaches existed for modeling the process of urbanization from different aspects of a city (Berling-Wolff and Wu, 2004), but describing it spatially based on remotely sensed data and GIS is still the most powerful and practical method.

Beijing is the capital of China, which experienced a very rapid process of urbanization in the past two decades after the reform and opening up policy carried out. This makes it a typical example for understanding the urbanization process and mechanisms in developing countries. Therefore, the urbanization of Beijing from 1984 to 2002 was analyzed in this paper by focusing on the following three problems: Firstly, how was the city urbanized in the past 18 years. Secondly, how different did it expand in different directions. And finally, what were the general driving forces responsible for the changes. By knowing these, future studies on detail mechanisms of urbanization and its environmental impacts will be beneficial from this study.

2. Study Site

Beijing is located in the north of China (Figure.1). Its area is about 16,808 km^2 and has a population of 13 millions at present. Beijing is a place as the centers of politics, economy, and culture in China,

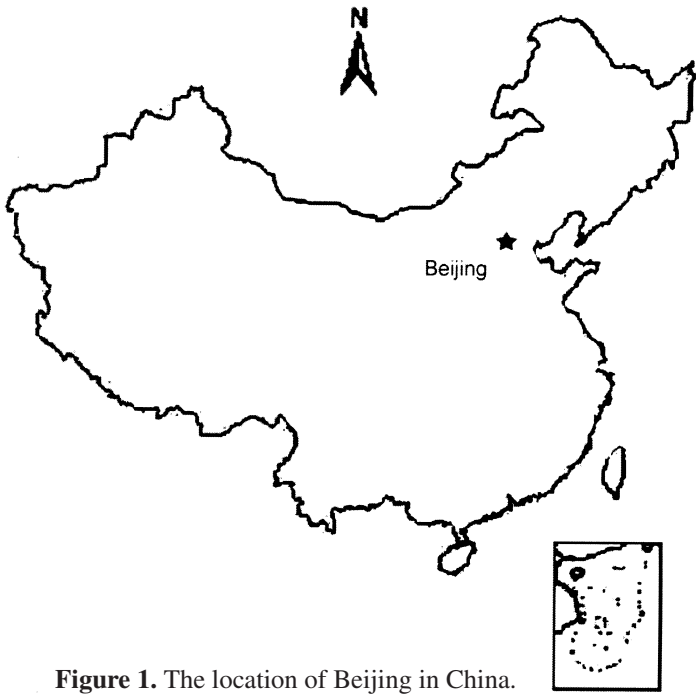

Figure 1. The location of Beijing in China.

Which has a history of more than 800 years, and became capital for 600 years since the Ming Dynasty. There are many ancient buildings well preserved, like the Forbidden City, the Great Wall and so on. Peking Opera exited over 200 years, which is regarded as the nation's opera of China. By 2005, the green space in Beijing will be more than 40%, that is, more than 10 m^2/person. Next Olympic Games will be held in Beijing in 2008, so that a new around of city construction and urbanization is ongoing.

3. Methods

Landsat TM data of Beijing region were used. They are of the years 1984, 1991, 1994, 1997, 1999, and 2002. The study area is within the 6th Ring highway. Figure 2 shows a comparison of the remotely sensed data between 1984 and 2002, which clearly indicated that Beijing city expanded significantly in the past two decades. The data were processed in ARCGIS using non-supervised classification, and five types were classified, they are water, greenspace, urban, farmland, and unused land. The landscape pattern analysis software, Fragstats, was employed to calculate the landscape metrics of the data, and totally 14 landscape indices were selected for the levels of landscape and urban type. For detail description on the software and these landscape metrics please refer to McGarigal and Marks (1993).

In order to describe the urbanization of Beijing in different directions, four transects on the images were sampled, they were transects: South-North, East-West, South West-North East, and South East-North West. Each transect was approximately 40 kilometers long centered at the Tiananmen Square, and

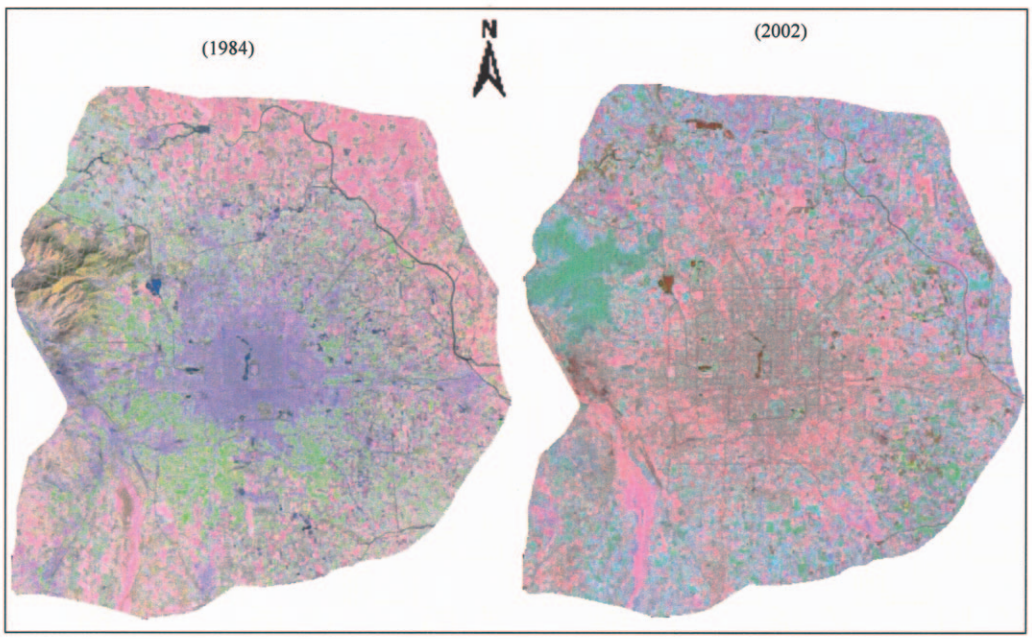

Figure 2. The rapid growth of Beijing city in the past 18 years shown by remotely sensed data (the merger of Landsat TM with Bands 3, 4, and 5). The central parts in the two figures (purple in 1984 and pink in 2002) were the urban areas.

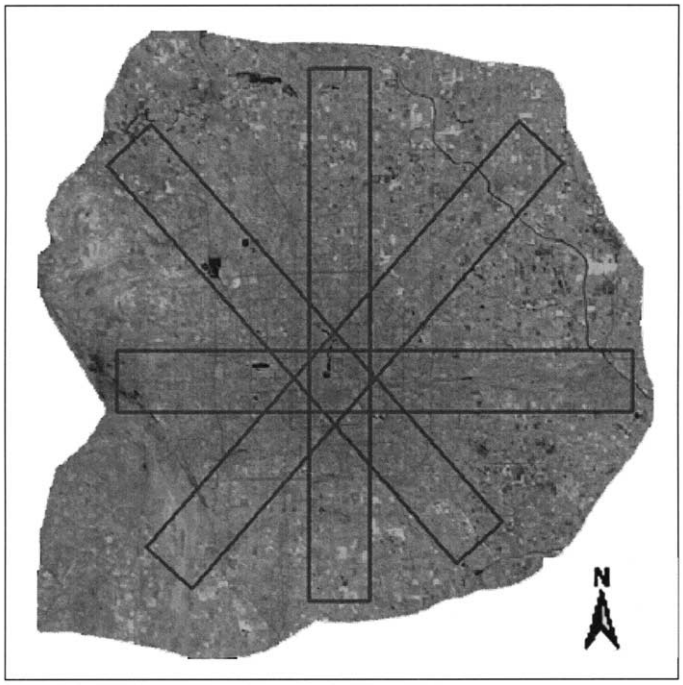

Figure 3. The four transects centered at the Tiananmen Square in Beijing sampled on the remotely sensed data (the merger of Landsat TM with Bands 3, 4, and 5).

was divided into grids of the size 2 km in length and 6 km in width. The urbanization rate was calculated within each grid, and a grid was determined as an urban area while the urbanization rate is higher than 50 percents.

4. Results

4.1. Landscape changes

Figure 4 shows that the landscape level indices of Beijing have different dynamics in the past two decades (those indices who are not statistically remarkable were omitted). The number of patches, patch density, landscape shape index, and edge density were concavely increasing; while mean patch shape index, mean nearest neighbor, and contagion were convexly decreasing. However, the Shannon diversity was linearly increasing with time. The variation of these indices indicated the landscape fragmentation in the process of urbanization.

4.2. Urban changes

Figure 5 shows the landscape index dynamics of Beijing during 1984 and 2002 at the urban type level (those indices that not statistically remarkable were omitted). Urban areas increased linearly; the mean patch size and the standard deviation of mean patch size were of single peak appeared in 1994; while the number of patches, patch density and edge density were concavely increasing. The overall trend of these

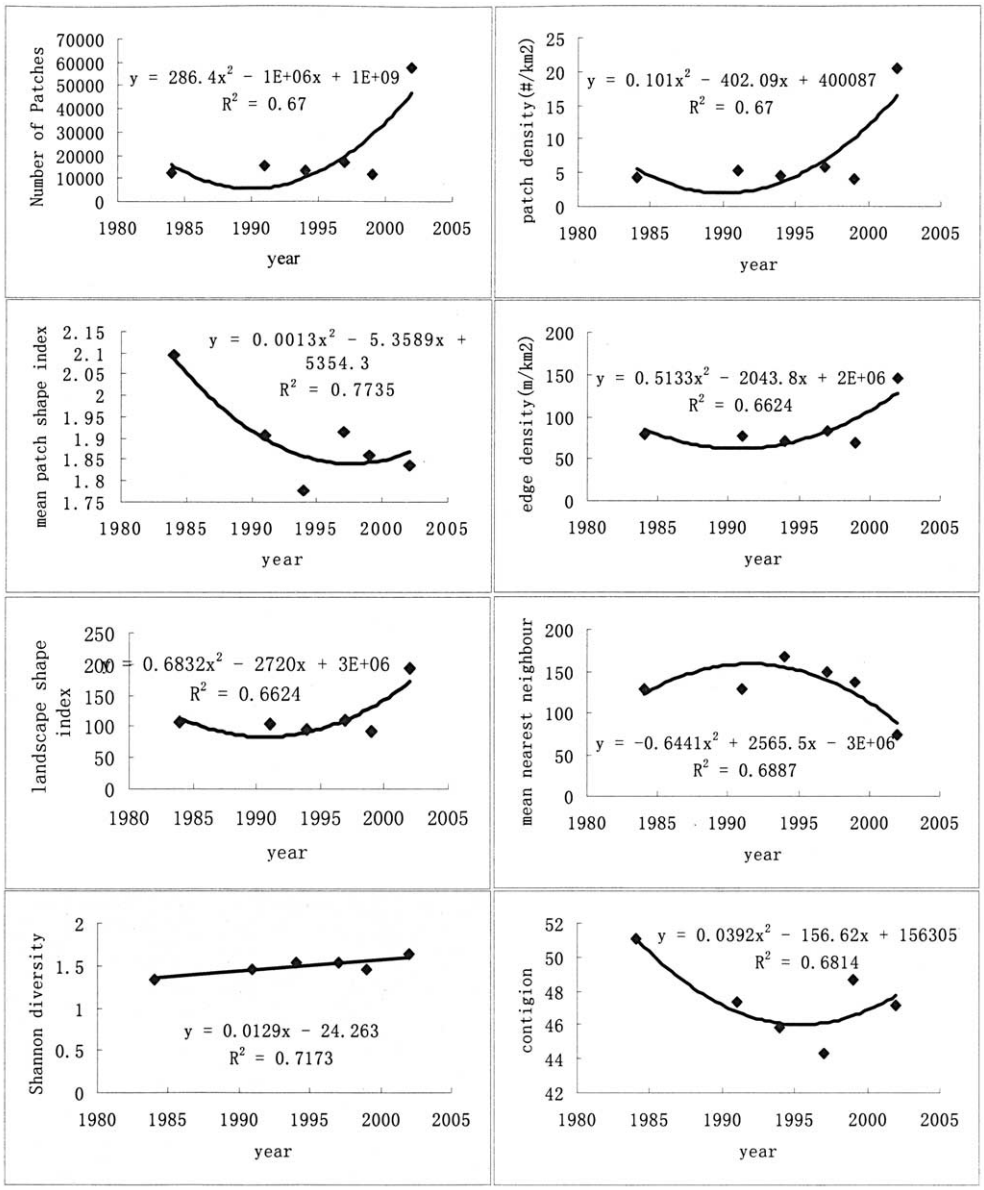

Figure 4. Landscape index dynamics of Beijing from 1984 to 2002 (the trend regressions $p<0.05$ while $R2>0.66$).

indices again indicated that the landscape was fragmented in the process of urbanization, but these indices are partly different from those at landscape level.

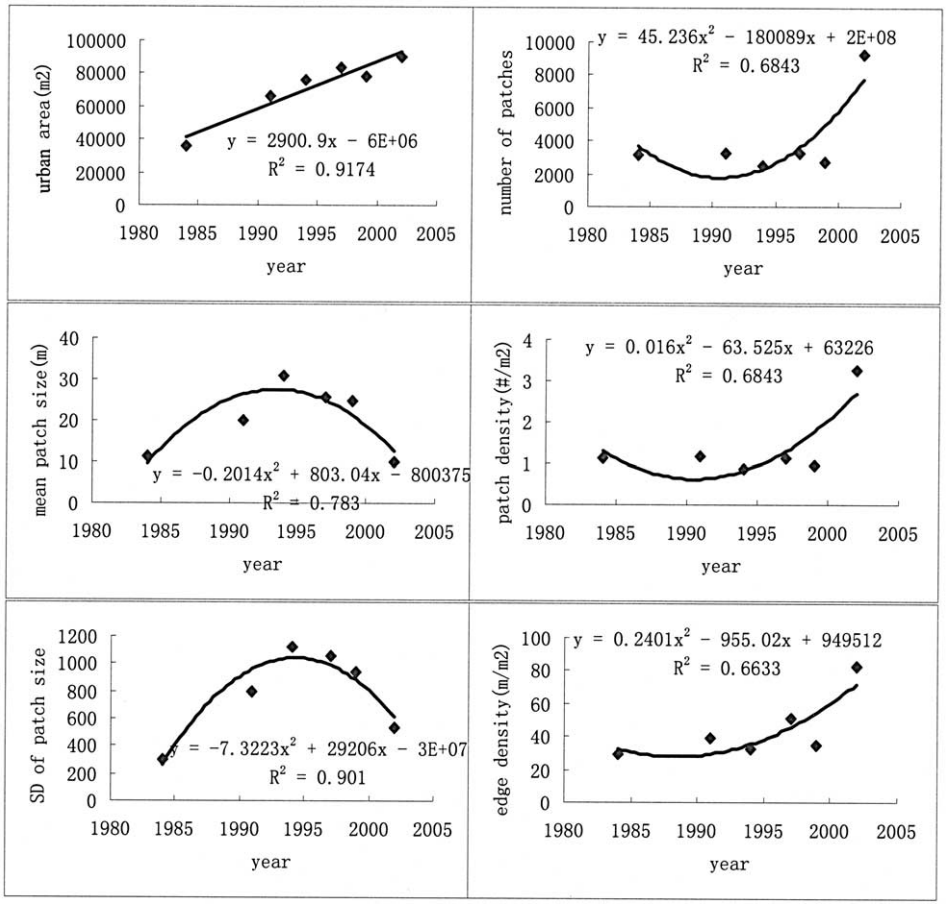

Figure 5. The landscape index dynamics of urban types in Beijing from 1984 to 2002 (the trend regressions $p<0.05$ while $R2>0.66$ and $p<0.01$ while $R2>0.85$).

4.3. Urbanization in different directions

Figure 6 shows that, on the one hand, the urbanization rate of the four directions of Beijing were the same in that they were all remarkably increasing from 1984 to 1994, but obviously decreasing from 1994 to 2002 in the central part of the city. On the other hand, the urbanization rates in the four directions were pretty different in details. The East-West transect shows that the urbanization rates of most areas were higher than 50% after 1984, which is mainly converted nonurban lands within the urban areas into urban lands, because the Changan Street at this direction has been kept as a main street in Beijing for several decades. The North-South transect shows a different property in that both north and south directions were developed into urban areas after 1984 at the distance of 10 km from the center. The other two transects had a similar trend of North-South transect, except that their shapes of line are more or less different in some parts. These three directions are mainly converted nonurban lands outside the urban areas into urban lands.

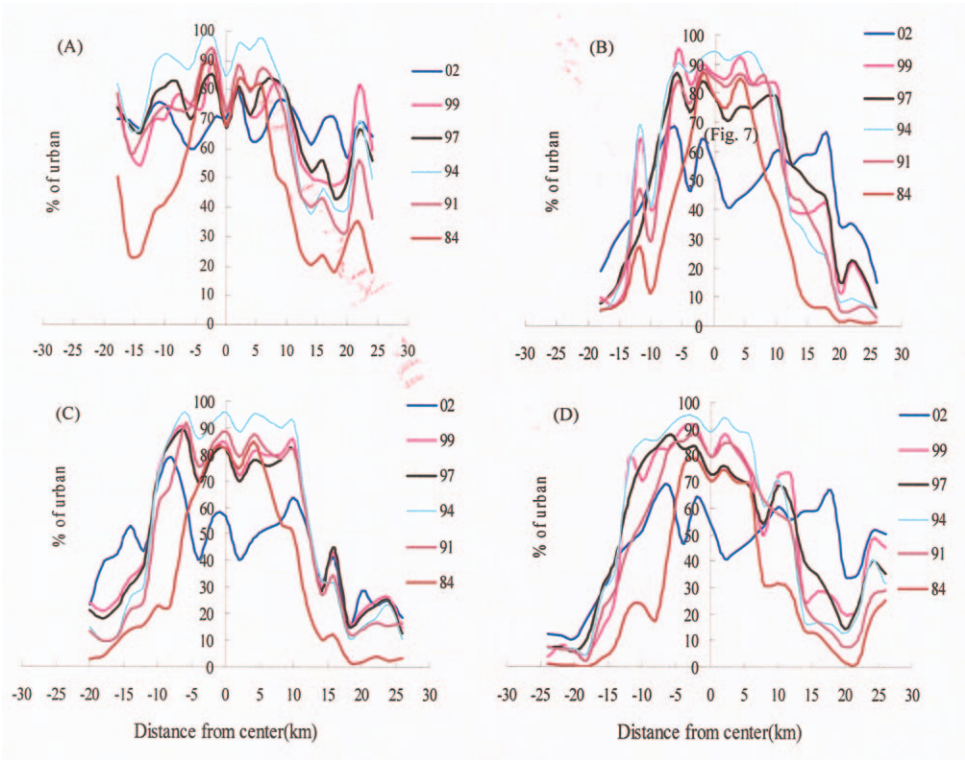

Figure 6. Urbanization rate in four directions in Beijing 1984-2002:
(A) East-West, (B) North-South, (C) Northwest-Southeast, (D) Northeast-Southwest.

If we determine the urbanization rate of higher than 50% as urban space, Figure 7 can be generated to show the moving urban fronts of the city in different directions at different years. It is obvious that Beijing city expanded greatly from 1984 to 1991 in all directions, and the main urbanization took place in East-West direction. In 1990's, it was mainly urbanized in North-South direction, but the increment was only at a small scale. However in 2000's, the city abruptly expanded in the Northeast and southeast directions, which especially happened in the Northeast direction. This 18 years urbanization whirled the city from Northwest-Southeast direction, to East-West direction, and finally to Northeast-Southwest direction, which made the city a pie shape in space.

5. Discussion

As mentioned above, there are many driving forces responsible for the urbanization of a city, and Beijing was the case in the past two decades. Firstly, the population of Beijing increased rapidly in the past two decades alongside the economy booming. The huge number of people with an improving living standard in the city (exceeded 13 millions in 2000's) needs more housing space and relevant infrastructures, which construction led to the landscape kept fragmented as indicated by the landscape metrics in Figures 4 and 5. For example, the highway construction has close relationship with this urban sprawl in

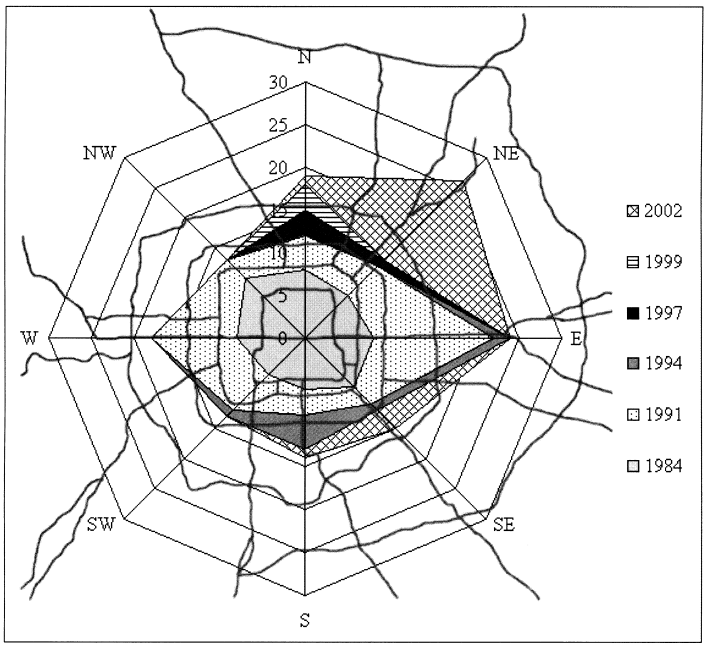

Figure 7. The map of urbanization in Beijing from 1984 to 2002 in different directions with an urbanization rate>50%. Where the orange curves are the six rings and highways of the city.

different directions (Figure 7).

Secondly, environmental protection in Beijing was another remarkable driving force in the past two decades. Particularly in recent years, there is an increasing demand for green areas and amenity spaces in urban centers due to recreation needs and growing environmental awareness. Green spaces provide aesthetic, ecological and economic benefits. They also include functions that have a physical and psychological effect on human health, such as air pollution control, noise reduction, improvement of microclimatological conditions, and provision of recreational opportunities (URBANCO, 1999; Tyrvainen and Miettinen, 2000; Damigos and Kaliampakos, 2003). The large scale greenspace constructions at the Beijing city center and along the highways led to the urbanization rate decreasing as shown in Figure 6.

Thirdly, because the north and west parts of Beijing are mountains, which geography obviously limited the urban expansion to those directions, and made the city sprawl mainly to the south and east plain regions as shown in Figure 7.

The present study is only a description on the urbanization of Beijing city in the past two decades, in order to explain the relationships between the urbanization process and the relevant driving forces clearly and quantitatively, a detail analysis on the driving forces and the establishments of some models to detect the mechanisms are needed. The greatest challenge facing cities is to create policy and a governmental framework for a sustainable development: an ideal policy that manages growth and development in ways that improve the quality of life for both urban and rural residents, and that minimizes the degradation of natural resources and habitats. These further studies on the mechanisms of urbanization and its environmental impacts will be beneficial from this case study in Beijing.

Acknowledgements

This study was funded by the Knowledge Innovation Program of Chinese Academy of Sciences, contract No. KZCX3-SW-424, and partially supported by the Hiroshima University COE (The 21st Century, Center of Excellence) program of Hiroshima University.

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