Analysis of Land use Changes and Environmental Loads during Urbanization in China

Haiyan Zhang*1, Michinori Uwasu2, Keishiro Hara2, Helmut Yabar2, Yohei Yamaguchi2 and Toru Murayama3

1 Research Fellow, Research Institute for Sustainability Science, Osaka University, Japan
2 Assistant Professor, Research Institute for Sustainability Science, Osaka University, Japan
3 Visiting Fellow, Ritsumeikan Research Center for Sustainability Science, Japan

Abstract

Urban expansion in China has led to rapid urbanization occupying a huge amount of cultivated land, and in turn, to adverse effects on city environments. By collecting data from 30 big cities in China, including the 4 biggest municipalities and 26 provincial government cities, this paper analyzes the current status of urbanization and identifies the land use changes as determined by a geographic information system (GIS) analysis. It also examines the relationships between urbanization level, the economy and environmental status, by applying a regression model. Finally, the paper proposes a perspective for promoting sound urbanization under the Circular Economy (CE) in China. The authors determined that 14,996 km² of cultivated land have been converted into urban built-up areas in China between 1990 and 2000. Above all, the changes in the three megalopolises of the Yangtze River Delta, Beijing-Tianjin-Hebei and the Pearl River Delta were substantial and the land use efficiencies of these areas are higher than in the other areas. The authors also found that urbanization is positively associated with per capita GDP. The regression analysis for per capita solid waste indicated an inverted-U shape relationship with urbanization.

Keywords: urbanization; Circular Economy; megalopolis, land use; environment

1. Introduction

With rapid industrialization and urbanization, China has experienced a shortage of land resources in recent decades and urban environmental problems have become very serious. To address these issues, the Chinese government, in the 11th five-year plan (FYP), clearly stated that China must create a new economic system that economizes resource consumption and promotes a Circular Economy (CE) to create an environmentally friendly society. The design and development of eco-cities is an especially important pillar of CE. Eco-city is a development process by which cities promote socio-economic development that respects the environment. In 2005, urbanization (the population in urban areas as a proportion of total population) in China reached 42.99%. Although urbanization has been expanding rapidly, the ratio is still below the world average of 48%. Since China will likely continue to increase its urbanization levels, it is important to pay special attention to environmental protection in urban areas. (Raising the level of urbanization ratio from 42.99% to 46.50% is clearly stated in the 11th FYP). Driven by global and local forces, in the next 20 years, China will likely achieve an urbanization level of 50-55%, which means an increase in the urban population from 405 to 675 million people. Although China has been experiencing rapid urban growth over recent decades, its urbanization rate is not matching the country's rapid industrialization progress. One of the consequences is that a greater amount of land around the cities will be exploited for housing, roads and other infrastructure (Gao & Zhang, 2002). At the same time, with urban expansion, longer travel distances and larger travel volumes have overburdened urban transportation systems. Extra fuel consumption, longer travel times and a high level of pollution not only lead to discomfort for road users, but also degrade the city's environment in general (Chen, Ganesan & Jia, 2005). The urban sprawl has been associated with heavy demand for new physical and social infrastructure. It is predicted that by 2050, China will need to invest 40 to 50 trillion RMB (1US$ = 8.25 RMB, as of 2004) to improve its urban infrastructure, equivalent to 800 to 900 billion RMB per year, which is about one-tenth of China's total GDP in 2001 (Chen, Jia & Lau, 2007). The need for improving urbanization and the relationship between urbanization and environmental
status have been discussed previously. However, these reports did not consider the relationship between urbanization and industrial structure, land efficiency and environment in Chinese cities.

In this study the authors collected data from 30 big cities (Fig.1.) in China including the 4 biggest municipalities and 26 provincial government cities. The current status of urbanization was identified, and clarification of land use changes determined by GIS analysis. The authors also analyzed the relationships between urbanization level and the economy, and environment status, by applying a regression model. Finally, the study proposes a perspective for promoting sound urbanization under the CE in China.

Fig.1. The Location of 4 Municipalities and 26 Provincial Government Cities in China

2. Urbanization and the Economy in China

2.1 Definition of Urbanization

In China, there are several classifications of urbanization. In terms of population, cities can be classified as small (less than 200,000 people), medium (between 200,000 and 500,000 people), big (between 500,000 and 1 million people), and large (more than 1 million people). In terms of administration and geography, cities can be classified as municipalities, provincial government cities, regional government cities and general cities. In terms of the economy, cities are classified as coastal, central and western.

The concept of megalopolises was introduced recently from abroad. At present, there are 10 megalopolises in China including the Yangtze River Delta (Shanghai, Jiangsu and Zhejiang), Beijing-Tianjin-Hebei, the Pearl River Delta (Guangdong), Shandong Peninsula (Jinan), the Central Liaoning City Cluster in China (Shenyang), the Central Plains (Zhengzhou), the Middle Streams of the Yangtze River (Wuhan), the west Side (Fuzhou), Sichuan-Chongqing (Chengdu, Chongqing) and Guanzhong Megalopolis (Xi'an) (6 megalopolises were selected, each with different location and economic characteristics, their detailed land use changes are discussed in Section 3 and shown in Figs.7.-12.).

Urbanization means the removal of the rural character of a town or area, a process associated with the development of civilization. Demographically, the term denotes the redistribution of populations from rural to urban settlements.

Urbanization also refers to the population concentrated in urban areas and the process of change from rural to urban areas. From these definitions of urbanization, at least the following two aspects have implications: population migration, which will inevitably lead to changes in the social structure of cities; and landscape change in the form of land use change and diversification of the use of resources (Liu & Chen, 2005).

In China, the level of urbanization is shown by the population in urban areas as a proportion of the total population.

2.2 Status of Urbanization in China

In recent years, urbanization has increased rapidly in China, and the rate of industrialization and economic development has accelerated. The changes in urbanization level are show in Fig.2. From 1980 to 1995 the average annual increase rate (AAIR) was only 0.64%. Between 1995 and 2000 the AAIR increased to 1.01%, but between 2000 and 2005 it jumped to 1.79%. The AAIR has been increasing by about 1.00% per year over the last 10 years. As noted previously, raising the level of urbanization from 42.99% to 46.50% is a clear declaration of the 11th FYP, which represents an average increase of about 1.00% per year.

Urban population density (UPD) and total floor space of buildings (TFSB) doubled between 2000 and 2005 (Fig.3.). UPD increased from 442 persons/km$^2$ in 2000 to 869.7 persons/km$^2$ in 2005. From 2005 TFSB is about 1,760 million m$^2$ each year. These statistics show that the amount of land needed for construction is increasing each year.

Among the above 30 municipalities and cities, in 2005, 24 had a UPD greater than the national average of 869.7 persons/km$^2$, and 24 had urbanization greater than the national average of 42.99% (Fig.4.).

Fig.2. Urbanization Changes in China (1980-2005)
Source: China Statistical Yearbook, 1990-2006

2.3 Urbanization and the Economy

The authors used the Stata9 software in order to analyze the relationships between urbanization level, and per capita GDP and urban tertiary industry (the
Urbanization is also a process by which primary industry GDP as a proportion of total GDP declines and that of secondary and tertiary industry increases. At the beginning of the economic reform of 1978, the government regarded secondary industry as an important pillar of reform. Recently the government has paid particular attention to developing tertiary industry to promote sustainable economic growth. Fig.6. shows that tertiary industry GDP, as a proportion of total GDP is positively associated with urbanization.

2.4 Ecological Process of Cities under the Circular Economy in China

The Shanghai government introduced the CE approach of Germany in its policies in 1998. In 2003 the CE theory was stipulated in the National Scientific Developmental Plan of China. Now China has introduced the CE model not only in industrial enterprises and eco-industrial parks, but also in cities/provinces and regions (Fig.16.). At the city/province level, Liaoning Province, Guiyang City, Panjin City, Rizhao City and Yima City passed the SEPA\textsuperscript{5} eco-examination in December 2004.

In October 2005, the first list of entities promoting CE was released by NDRC\textsuperscript{5}, SEPA\textsuperscript{5}, MOST\textsuperscript{5}, MOF\textsuperscript{5}, MOFCOM\textsuperscript{5} and STATS\textsuperscript{5}. The list includes important industries and sectors: 13 industrial parks and 10 provinces/cities (Beijing, Shanghai, Jiangsu, Liaoning, Shandong, Chongqing, Guiyang, Ningbo, Hebi and Tongling).

3. Land use Changes in China

3.1 From Cultivated Areas to Built-up Areas

The authors used ArcGIS\textsuperscript{6} to analyze changes in land use. Fig.3. shows the large amount of construction, which led to the transformation of the area under cultivation. Because land use changes in cities could not be determined exactly and clearly, the authors studied land use changes in provincial areas. From 1990 to 2000, about 14,996 km\textsuperscript{2} (an area equivalent to about 2.37 times that of Shanghai city) of cultivated land have been changed to urban built-up areas in China. Among the four megalopolis municipalities, the most changed was Beijing (742 km\textsuperscript{2}), followed by Shanghai (393 km\textsuperscript{2}), Chongqing (207 km\textsuperscript{2}) and Tianjin (75 km\textsuperscript{2}).

The land use changes of the selected six megalopolises are shown in Figs.7-12. In the figures, the land use changes from 1990 to 2000 are indicated in accordance with the six categories of degrees (0 km\textsuperscript{2}, 1-2,000 km\textsuperscript{2}, 2,001-4,000 km\textsuperscript{2}, 4,001-6,000 km\textsuperscript{2}, 6,001-8,000 km\textsuperscript{2}, and 8,001-10,000 km\textsuperscript{2}). The top three megalopolises that were subject to large changes include the Yangtze River Delta (3,269 km\textsuperscript{2}), Beijing-Tianjin-Hebei (2,897 km\textsuperscript{2}), and the Pearl River Delta.
(992 km$^2$). The total area of the change in these three megalopolises was 7,158 km$^2$, which is about 47.7% of the total area of China that has been converted from cultivated to urban built-up areas.

### 3.2 Land Efficiency of Cities

In this study, the authors defined land efficiency (LE) as the value of regional GDP/km$^2$ and used it as an indicator to investigate economic efficiency of the cities. Since the demand for land increases with rapid growth of urbanization, the authors considered that it is important to improve LE. The calculated LE according to the 30 cities is shown in Fig.13.

At the city level, Shanghai has the highest LE, 139.9 million Yuan/km$^2$, whereas Xining has the lowest LE, 3.09 million Yuan/km$^2$.

At the megalopolis level, the Yangtze River Delta has the highest LE, 19.55 million Yuan/km$^2$. Although it accounts for only 2.2% of China's total land area, it produces 22.3% of total GDP.

The LE of the Pearl River Delta is 12.6 million Yuan/km$^2$. Although it accounts for only 1.9% of the total area it produces 12.2% of total GDP.

The LE of Beijing-Tianjin-Hebei is 9.6 million Yuan/km$^2$. While it accounts for about 2.2% of the total...
area, it produces 11.3% of total GDP.

This analysis shows that land use in agglomerations of towns and cities can improve LE, as has occurred in the three megalopolises of the Yangtze River Delta, Beijing-Tianjin-Hebei and the Pearl River Delta (Fig.13.), while the LE in coastal areas is higher than central and western areas.

Although further analysis is needed, one direction for China's future might be to improve LE by adopting relevant policies such as changes in urbanization from 42.99% to 46.50%, which is a clear declaration of the 11th FYP, and adjusting industrial structure.

4. Environmental Status and Urbanization

In general, both economic development and urbanization adversely affect the environment. However, it has been argued that at some point during the process of economic development, environmental status starts to improve, a theory known as the environmental Kuznets curve (EKC) hypothesis. The mechanism of EKC include industrial structural shifts and people's preference changes. As an economy grows, there is a shift from manufacturing to service industries, which reduces the level of pollutant emissions. As citizens become more prosperous as a result of economic growth, they typically prefer a better environment, which makes environmental regulations or even taxes more acceptable.

Many studies have been conducted to test the EKC hypothesis (Hayami 1995). The authors selected total emissions of SO$_2$ and per capita solid waste discharge as representative indicators of environmental status in this study. The results for the regression between total emissions of SO$_2$ and urbanization based on city level data, which were determined first, indicated the U-shape relationship, which is an unexpected result (Regression results are available from the authors upon request). This result might be due to sample selection. Basically, the negative sign of the first order term of per capita GDP indicates a downward slope, showing that the cities in the sample have already reached a level from which total emissions of SO$_2$ are decreasing. The authors carried out the same regression using provincial data, which suggests an inverted-U shape relationship, as indicated in note 7 (Fig.17.). Therefore, this discussion will focus on the provincial data. Per capita SO$_2$ emissions (Fig.14.) showed no obvious relationship with urbanization. Because such emissions are caused mainly by the large-scale use of coal in China, it is inevitable that clean production methods and use of clean energy will decrease the indicators of energy consumption and introduce high-tech industry production.

The regression results for per capita solid waste show an inverted-U shape relationship with urbanization (Fig.15.). This result therefore supports the EKC hypothesis. One reason for this result could be the recent trend for polluting industries that discharge solid wastes to move out of large cities. Another reason might be that industrial waste recycling has recently been promoted among commercial enterprises. In fact, in the three big megalopolises, many eco-cities have cooperated to facilitate the recycling of materials and energy. For example in Beijing, Shanghai, Zhejiang, Jiangsu, Tianjin and Guangdong, factories have been
set up to recycle plastic, e-waste and metal. The regression results also show that solid waste production will decrease when it crosses the top of the curve, so that the city can reduce the area of landfill to increase the LE as urbanization increases. This topic will be the subject of future research.

5. Conclusion

As the rate of urbanization in China increases, an increasing number of conflicts concerning land use and environmental protection will constrain urban development.

From this study, it can be conclude that, 1) a large amount of cultivated land has been converted into built-up urban areas in China. The LE of the three megalopolises in the Yangtze River Delta, Beijing-Tianjin-Hebei and the Pearl River Delta is higher than that of the other megalopolises; 2) urbanization is positively associated with per capita GDP. The regression results for per capita solid waste showed an inverted-U shape relationship with urbanization.

In order to develop sound urbanization, the following points should be carefully considered:

1) A megalopolis could be a good form of urban structure in China, as it can potentially improve the economy and social development, and increase land use efficiency, if it is effectively controlled. From the environmental perspective, material recycling and efficient energy use should be further promoted within the megalopolis.

2) Increasing tertiary industry as a proportion of total industry can decrease environmental pollution. Clean production methods and use of clean energy will decrease the indicators of energy consumption, improve high-tech industry production, and build a sound urban ecological system.

Acknowledgements

This work was supported by MEXT through Special Coordination Funds for Promoting Science and Technology, as a part of the Flagship Research Project for Development of an Asian Closed-loop Society, undertaken by Osaka University.

Notes

1. Circular Economy (CE): it is in essence an eco-economy, which features low consumption of materials and energy resources, low emissions of pollutants and high efficiency. In China there are several CE models with different circulation levels: small, medium and large. Small circulation promotes cleaner production (CP) within individual firms. Medium circulation promotes eco-industrial parks. Large circulation promotes the CE in cities, provinces and regions (Fig.16.).

2. Megalopolis (http://en.wikipedia.org/wiki/Megalopolis) is an extensive metropolitan area or a long chain of continuous metropolitan areas. In China, the 10 megalopolises comprised only 9.99% of the total area and 35.02% of the total population, but contributed 52.83% of the total GDP in 2005. In this paper, only the provincial cities were selected from the 10 megalopolises.

3. http://en.wikipedia.org/wiki/Urbanization.

4. STATA9 is a data analysis and statistical software. It is used for data analysis, data management, and graphics, containing matrix programming, widely used in academia and international research institutes. It is provided by StataCorp LP, USA. Its world wide web is http://www.stata.com/.

5. SEPA: State Environmental Protection Agency, NDRC: State Development and Reform Commission, MOST: Ministry of Science and Technology of the People's Republic of China, MOF: Ministry of Finance of the People's Republic of China, MOFCOM: Ministry of Commerce of the People's Republic of China, STATS: National Bureau of Statistics of China.

6. ArcGIS9.0 is a geographic information system. It is a computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the earth. All spatial data employed for this paper are provided by the China Data Center.

7.
References
1) Gao, X. D. and Zhang, S. Y. (2002) Study on suburbanization and sustainable development in Shanghai. China Population, Resources and Environment, 12(1), 76–80.
2) Deng, X., Huang, J., Rozelle, S. and Uchida, E.(2006) Cultivated land conversion and potential agricultural productivity in China. Land use Policy, 23, 372-384.
3) Chen, H., Jia, B. and Lau, S. (2007) Sustainable urban form for Chinese compact cities: Challenges of a rapid urbanized economy. Habitat International, doi:10.1016/j.habitatint.2007.06.005
4) Fritz, J. and Vollmer, D. (2006) To what extent can technology compensate for institutional failure in an urban environmental management setting: The case of China. Technology in Society 28, 95-104.
5) China Statistical Yearbook, 1990-2006.
6) China City Statistical Yearbook, 2006.
7) Liu, Y., Chen, F. and Li, R. (2007) Simulation of regional urbanization and eco-environment coupling and regulation policies: taking Jiangsu Province as a case. Geographical Research, Vol.26, No.1. (In Chinese).
8) Yujiro Hayami. (1995) Development Economics, Sobunsha. (In Japanese).