Modelling Urban Land Use Dynamics under the Restriction Scenarios of Water Resource in Beijing

HUANG Qing-xu1, 2, SHI Pei-jun1, 2, *HE Chun-yang1

1. State Key Laboratory of Earth Surface Processes and Resource Ecology, Beijing Normal University, Beijing, 100875, China

2. Academy of Disaster Reduction and Emergency Management, Ministry of Civil Affairs & Ministry of Education, Beijing Normal University, 100875, China

ABSTRACT: Water resource is the most essential natural resource restricting the exploitation and utilization of land resources, especially in large urban areas. With the development of economy and urbanization, the limitation of water resource become more and more obvious in Beijing and the influence on the land use dynamic turns out to profound.

Based on water resource carrying capacity (WRCC), a principle indicator of water resource security, a System Dynamic (SD) model under water restriction with the aim to simulate land use scenarios change in the Beijing before 2030 is developed in this research. The model combines the socioeconomic factors (GDP, population) and natural factor (WRCC) to simulate several scenarios of land use change with the restricted element of water in Beijing. The accuracy assessment with the historic data covering 1980 to 2003 indicates the SD model is reliable and helpful to understand the restriction of water resource to social development.

The scenarios results suggest that, in Beijing, water resources will vary largely, from 16.4 km3 to 45.4 km3 under different water restriction scenarios. By restricting population and economy growth, water resource adjusts the land use structure extremely in Beijing. It indicates that the cultivated land and buildup land are the top two types of land most affected by the water resource, so, the conflict between buildup land and cultivated land is the main problem in the future. In other words, controlling urban expansion and protecting cultivated land are essential approaches in urban area in the future.

Keywords: water restriction; water capacity; urban land use change; scenario simulation; system dynamic model

1. Introduction

Water is the critical natural resource for social and economic development and security. 300 m^3 is the amount of available water resource for every resident in Beijing. It's below the severe water shortage threshold, 500 m^3, and about 1 of 30 to the global average degree (UNDP, 1990). Therefore, the situation of water resources is of great severity in Beijing. The effects of water shortage become more and more obvious in Beijing. Concerning the global climate change and the aridificational trends in north of China (Ding *et al.*, 2006), we should put forward research how to deal with the tough condition. Amount of water resources can be influenced by following ways: (1) natural climate change, 2) advance in technology, (3) market regulation, and (4) public awareness. In this research, we use System Dynamic (SD) method to construct a model simulating water resource dynamics and land use change under different scenarios. By scenario experiments and results comparison, this model is useful to guide and support the response strategies to manage the water resource in Beijing.

2. Study Area and Data Source

Beijing is the capital city of China. It locates in temperate continental zone. Annual precipitation ranges from 500 mm to 800 mm with high variations, and annual temperature fluctuates between 11°C to 12°C. There are five river systems distributing in Beijing, including Jiyun river, Chaobai river, Beiyun river, Yongding river and Daqing river from the east to the west. Annual yield water resource is about 3.768 billion m^3. Immigrating water and precipitation stand the main components of available surface water in Beijing, although the water quality is strongly affected by the exploitation and utilization of upstream water resources.

Social-economic data, meteorological data and the water resource data are from Beijing Statistical Yearbook (1990-2006), Standard Meteorological Data Sets compiled by China Meteorological Administration, and Beijing Water Resource Yearbook (1997-2006) respectively. By analyzing these data sets, Beijing is undergoing a rapid economic and social development (Figure 1), and there is a prominent aridification trend in Beijing (Figure 2, 3).

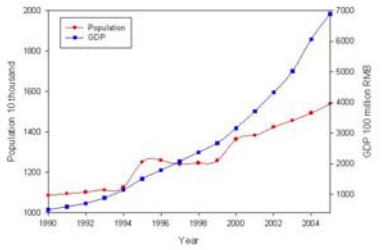

Fig.1 Population and GDP growth in Beijing

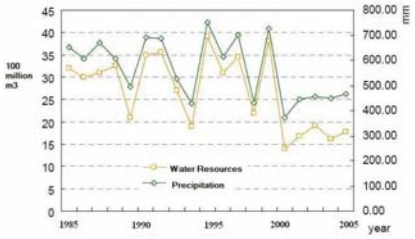

Fig. 2 Water Resource Change in Beijing

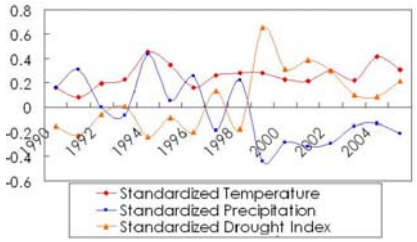

Fig. 3 Dynamics of precipitation, temperature and drought index in Beijing

3. Methodology

System Dynamic Model is a reliable and flexible simulating tool to combine complicated feedbacks together. The framework describes the main sub-system in the model (Figure 4) and the structure explains the feedbacks between variables (Figure 5). Five scenarios are designed to examine effects by different driving forces and analyze possible solutions (Table 1).

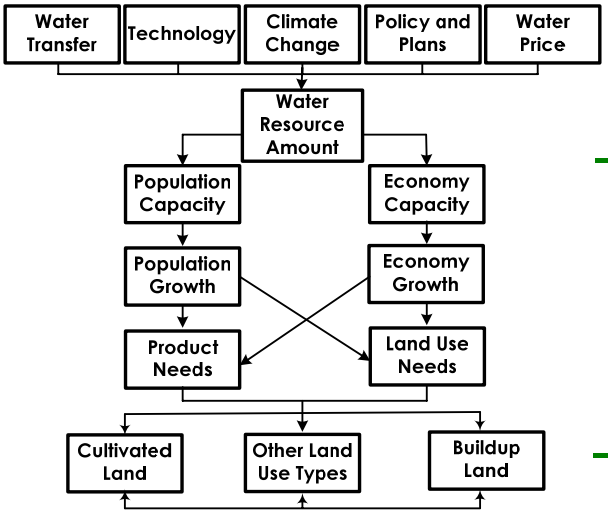

Figure 4 Framework of model in Beijing

Tab. 1 Five Scenarios for Land Use Dynamics in Beijing from 2006-2030

Scenario No.	Climate Change	Water Transfer	Progress in Technology	Restriction
A	×	×	×	×
B	√	×	×	√
C	×	√	×	√
D	×	×	√	√
E	√	√	√	√

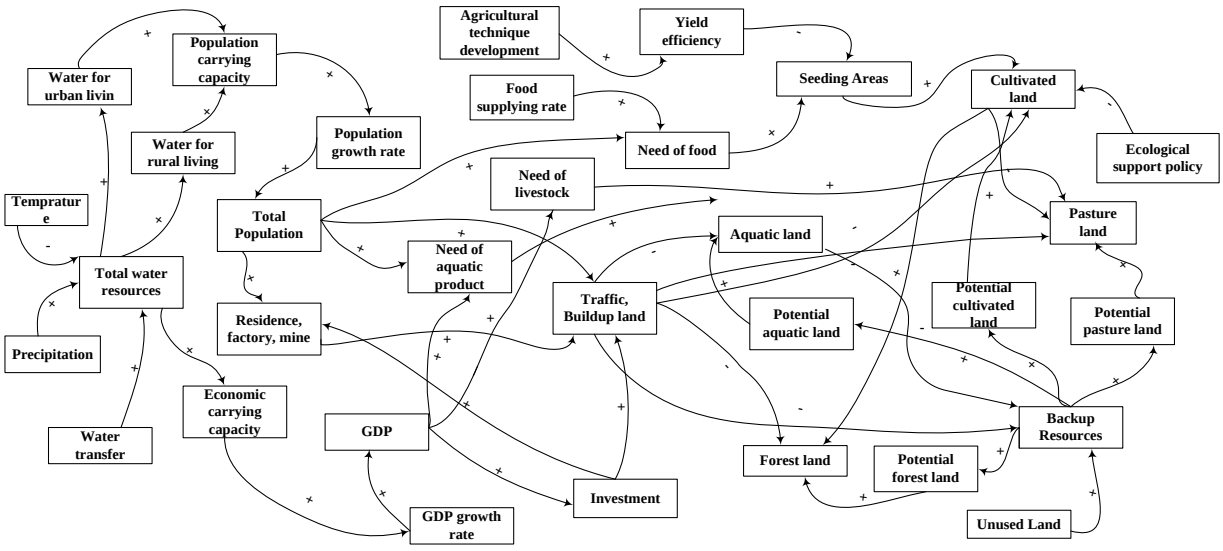

Figure 5 Structure of System Dynamics model in Beijing

4. Results and Discussion

We develop and modify existed model in Beijing (Wang *et al*., 2006), adding the variables indicating the climate change effects to water resources. The results are compared among scenarios (Table 2, Figure 6). From the results, it's clear that: (1) Water resource are strongly affected by water restriction, and the climate change trend in North make it worse, whereas water transfer and progress in technology will relieve the effect. (2) Population and GDP growth are restricted by water resource, especially GDP growth. (3) Croplands are greatly constrained by water resource, and buildup land is

sensitive to water resource change too.

Tab. 2 Comparison amid Scenarios Results

Year	Scenario	Water Resource	Population	GDP	Crop Land	Buildup Land
		100 million m^3	10 thousand	100 million RMB	Km^2	Km^2
2000		17.79	1384.93	3,628.71	386942.46	276842.98
	A	27.92	2164.93	25339.74	357023.32	442456.56
	B	18.16	1570.29	6896.38	387354.10	326854.42
2020	C	41.92	1789.63	14120.78	343575.19	369117.09
	D	69.79	1865.95	23462.72	311303.31	383588.27
	E	64.31	1888.92	21724.74	315381.78	388486.71

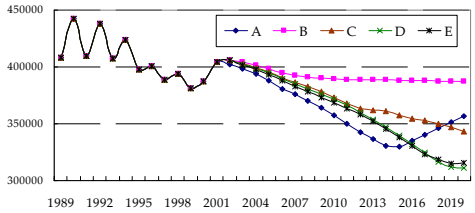

Fig. 6-a Cropland change

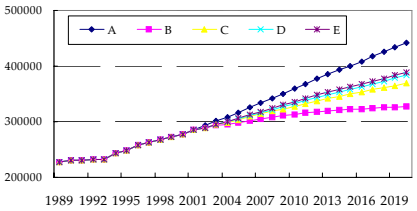

Fig. 6-b Buildup land change

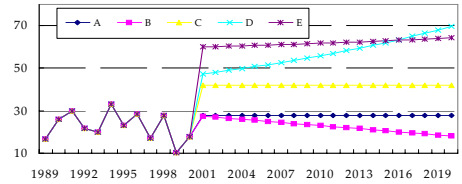

Figure 6-c Water resource change

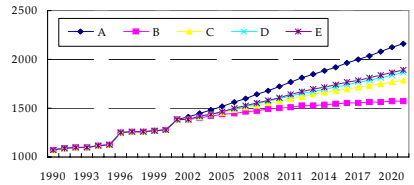

Figure 6-d Population growth

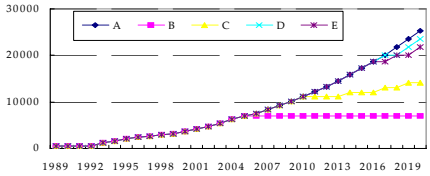

Figure 6-e GDP growth

Fig. 6 Variables dynamics under different scenarios

5. Conclusion

System Dynamic model is an efficient tool to simulate the feedbacks among land use system variables, and the result indicates possible changes under scenarios. Such kind of “as-if” experiments will play a role in regulating and managing land use plan. The results show that water resources will become a vital factor restricting social and economic development, therefore has indirect effects on land use dynamics. Water transfer projects and progress in technology will alleviate the severe condition stimulated by water resource shortage.

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