AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Land Use Change and Driving Forces in Guangzhou City during 1996 - 2012

Yiying YAO[1], Dafang WU[1]*, Yanyan LIU[2], Yihua LIU[1], Qixian CHEN[1], Haolong CHEN[1], Jiaxin WU[1], Jialiang ZHONG[1]

1. School of Geographical Sciences, Guangzhou University, Guangzhou 510006, China; 2. Civil Architecture Science Research and Design Institute of Guangzhou, Guangzhou 510055, China

Abstract Based on the statistical data of land use change, from the perspective of sustainable use, we use literature inquiry, statistical analysis, GIS spatial analysis and dynamic degree model of land use, to analyze the land use change characteristics, land use amount and spatial distribution characteristics in Guangzhou City during 1996 - 2012, and further elaborate the driving forces of land use change to get the basic law of land use change in Guangzhou City. The results show that the construction land was rapidly expanded, causing a significant reduction in arable land (from 129286 ha in 1996 to 84567 ha in 2012); in construction land, the land for residential, industrial and mining use and transportation land dramatically increased, and the single dynamic degree of transportation land was close to 7.1%. In comparison with other developed cities, it is found that economic factors and policy factors are important factors affecting land use change in Guangzhou City, and the growth rate of economic density of land was high in Tianhe District and Yuexiu District. From the perspective of sustainable use, the future land use in Guangzhou City needs to better coordinate the relationship between various types of land, between socio-economic development and coordinated land use development, between environmental protection and land development and utilization. Through a series of land consolidation activities, it is necessary to strengthen the protection of farmland, improve the intensive and economical use of construction land, improve the ecological environment, and coordinate development of urban and rural areas, to ultimately achieve sustainable land use in Guangzhou City.

Key words Land use change, Driving forces, Sustainability, Guangzhou City

1 Introduction

LUCC (Land-Use and Land-Cover Change) is an important part causing global change, and many scholars lay great emphasis on the study of driving mechanism of LUCC[1]. In 1995, the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme (IHDP) jointly proposed the scientific research project on LUCC to which the experts and scholars from various counties attached importance[2-8]. Currently, LUCC research methods have developed towards the direction of comprehensive development, and emphasize integrated treatment of a variety of methods. 3S technology is used to analyze LUCC as well as its driving forces[9-12]. With the rapid development of China's economy, many experts and scholars have explored LUCC of China's cities[10-21]. Luo Ya uses three indicators (land-use change importance index, land-use change area proportion, and vegetation change index) to analyze the land use change in Hekou Town-Tongguan during 1998 - 2010[10]. Based on regional land use change, Gao Zhiqiang uses the dynamic environmental model to simulate land use situation in China[11]. Fang Xiuqin uses decision tree and SVM method to analyze the land use change in Laohahe River basin over the past four decades[12]. Ye Xin *et al.* analyze the land use change trend and driving forces based on CA model[13]. Taking Guangzhou City for example, Zeng Juan analyzes the carbon emission effect of land use change in Guangzhou City[14]. Gong Jianzhou *et al.*[15-16] analyze the optimization of land use structure in Guangzhou City and land use potential. Liao Jiwu *et al.*[17] use GIS technology to analyze the influence of ocean on land use change in coastal zone. Chen Minghui[18] takes Nantuo District of Guangzhou City for example to analyze the dynamic changes in land use structure on the urban fringe. The existing studies focus on the correlation analysis of urban land use change, because the data is difficult to obtain, and it often lacks the comparative analysis of long time series land use data. Therefore, for the Pearl River Delta, carrying out long time series land use change analysis is of important practical significance to local socio-economic development[22-24]. Based on the survey data on land use change, this paper analyzes the overall situation and characteristics of land use change in Guangzhou City during 1996 - 2012, and explores the factors influencing land use change in Guangzhou City in order to promote sustainable land use in Guangzhou City.

Received: May 28, 2015 Accepted: July 22, 2015

Supported by National Natural Science Foundation of China (41101078, 41401191); General Humanities and Social Sciences Research Project of the Ministry of Education (13YJA790074); Guangdong Natural Science Foundation (S2013010014526); Innovation Project of Guangdong Provincial Department of Education (2014KTSCX090); Guangdong "Twelfth Five-Year Plan" Education and Research Project in 2013 (2013JK134); General Research Project of Guangzhou Municipal Universities (2012A014); Guangzhou "Twelfth Five-Year Plan" Education Science Project (12A037); Guangzhou "Twelfth Five-Year Plan" Philosophy and Social Sciences Project in 2015 (15Q28); College Students' Innovative Training Program of Guangdong Provincial Department of Education (201411078056, 201411078057, 201511078019, CX2015025).

* Corresponding author. E-mail: wudaf2004@163.com

2 Study area and data sources

2.1 Study area Guangzhou (112°57′ – 114°3′E, 22°26′ – 23°56′N) also known as Canton, is the capital and largest city of Guangdong Province in South China. Located on the Pearl River, about 120 km north-northwest of Hong Kong and 145 km north of Macau, Guangzhou serves as an important national transportation hub and trading port. One of the five National Central Cities, it holds sub-provincial administrative status. Guangzhou is the third largest Chinese city and the largest city in South Central China. Some estimates place the population of the entire Pearl River Delta Mega City built-up area as high as 44 million including Guangzhou's nine urban districts, Shenzhen (10.36 million), Dongguan (8.22 million), Zhongshan (3.12 million), most parts of Foshan (7.20 million), Jiangmen (1.82 million), Zhuhai (0.89 million) and Huyang County of Huizhou (0.76 million) adjoining Dongguan and Shenzhen, with an area of about 17573 km^2[16]. Located in the south-central portion of Guangdong, the city is part of the Pearl River Delta and the city center is situated next to the Baiyun Mountain. The total area under the city's administration is 7434.4 km^2. The elevation of the prefecture generally increases from southwest to northeast, with mountains forming the backbone of the city, and the ocean comprising the front. In 2012, Guangzhou's GDP reached 1355.121 billion yuan, ranked first in the nation. With the growing population, Guangzhou is facing environmental degradation, resource shortages, rapid expansion of construction land, irrational land use structure and other issues. The analysis of land use change and its driving forces in Guangzhou City can better promote the sustainable development of Guangzhou.

2.2 Data sources Through a review of relevant literature on land use data in Guangzhou City, we study the land use change and its driving forces, and use the base period data of overall land use planning in Guangzhou as auxiliary data, for the analysis and comparison of land use change data over the years in Guangzhou City. Through processing, the land use data (1996, 2000, 2005, 2012) and data analysis chart of various land use types in Guangzhou City are obtained.

Table 1 Land use change in Guangzhou City during 1996 – 2012

Land use types		1996		2000		2005		2012		Rate of change %
		Area ha	Proportion %	Area ha	Proportion %	Area ha	Proportion %	Area ha	Proportion %	
Agricultural land	Arable land	129286	18.30	118460	16.50	104149	14.30	84567	11.80	-34.6
	Garden plot	84838	12.00	96267	13.40	110827	15.20	108114	15.10	27.4
	Woodland	285849	40.40	279178	39.00	269578	37.00	258937	36.20	-9.4
	Grassland	229	0.03	225	0.03	195	0.03	126	0.01	-45.1
	Other agricultural land	35644	5.00	42249	5.90	52349	7.20	66349	9.30	86.1
	Subtotal	535846	75.80	536379	74.80	537098	73.70	518093	72.40	-3.3
Construction land	Land for residential, industrial and mining use	95432	13.50	110275	15.40	128196	17.60	139973	19.60	46.7
	Transportation land	12686	1.80	14264	2.00	16586	2.30	20648	2.90	62.8
	Irrigation works land	10642	1.50	11450	1.60	9327	1.30	7986	1.10	-24.9
	Subtotal	118760	16.80	135989	19.00	154109	21.10	168607	23.60	41.8
Unused land	Unused land	21856	3.10	17574	2.50	9738	1.30	4599	0.60	-78.9
	Other land	66978	9.50	53498	7.50	42495	5.80	24451	3.40	-63.5
	Subtotal	88834	12.60	71072	9.90	52233	7.20	29050	4.10	-67.3

3 Analysis of land use structure in Guangzhou City

3.1 Analysis of changes in land use amount In 1990, the total land area of Guangzhou was 706799 ha, including 129344 ha of arable land, 212 ha of grassland, 285547 ha of woodland, 12722 ha of transportation land, 95418 ha of land for residential, industrial and mining use, and 21911 ha of unused land. Compared with 1990, the total land area was 728655 ha in 2005, including 104198 ha of arable land, 110756 ha of garden plot, 219 ha of grassland, 269602 ha of woodland, 128243 ha of land for residential, industrial and mining use, 16759 ha of transportation land, and 9473 ha of unused land. With the further development of the economy, the total land area was 731260 ha in 2012, and there were great changes in the land use amount. The area of arable land was 84567 ha, accounting for 11.8%; the area of garden plot was 108114 ha, accounting for 15.1%; the area of woodland was 258937 ha, accounting for 36.2%; the area of grassland was 126 ha, accounting for 0.01%; the area of land for residential, industrial and mining use was 139973 ha, accounting for 19.6%; the area of transportation land was 20648 ha, accounting for 2.9%; the area of unused land was 8978 ha, accounting for 0.6%. Table 1 shows that with the acceleration of social development and urbanization, the overall trend of land use structure change in Guangzhou City during 1996 – 2012 was that construction land increased year by year while agricultural land and unused land continued to decline. In 1996 – 2012, there were significant changes in the land use amount, and arable land and woodland were reduced greatly, which had some adverse effects on sustainable development and ecological city construction. At the same

time, the increase of land for residential, industrial and mining use and transportation land indicates that the city continues to grow, and we need more rational planning and guidance. In 2012, the used land area was 702210 ha, and the land utilization rate reached 96%. During 1996 – 2012, the area of arable land greatly decreased, down from 129286 ha in 1996 to 84567 ha in 2012, and the proportion declined from 17% to 11%; woodland also decreased, from the original 39% to 36% in 2012; the area of garden plot rose, from 11% in 1996 to 15% in 2012. Meanwhile, the area of other land in unused land decreased from 66978 ha in 1996 to 4599 ha in 2012, and the proportion fell from 3% to the current 0.6%; the area of construction land significantly increased, and the area of land for residential, industrial and mining use constantly increased, from the original 13% to 19% in 2012.

3.2 Analysis of rate of land use change The dynamic degree of land use change refers to the rate of annual change in land use amount, and it can be used to measure the rate of land use change according to the change in the amount of a certain land use type in a certain area at a certain time[25-26]. The dynamic degree of land use mainly uses the dynamic change in land use in different periods for analysis[27-28]. The dynamic degree of land use can better reflect the change in land use type to some extent[30-32]. The dynamic degree of land use change in Guangzhou City during 1996 – 2012 is calculated as follows[29]:

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

where K is the dynamic degree of a certain land use type in the study period; U_a and U_b are the amount of a certain land use type at the beginning and end of the study, respectively; T is the length of study period, and when T is year, the value of K is the rate of annual change in a certain land use type in the study area.

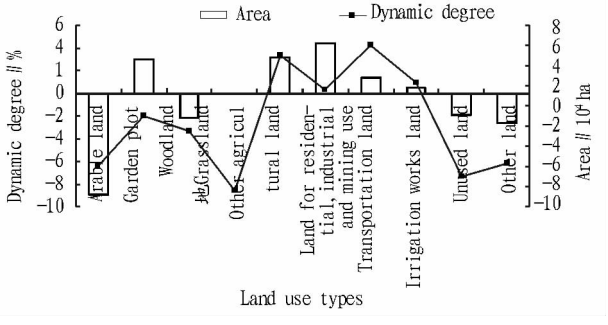

Fig. 1 The land use change in Guangzhou City during 1996 – 2012

As can be seen from Fig. 1, during 1996 – 2012, there was an increase in the land for residential, industrial and mining use, transportation land, irrigation works land and other agricultural land, while there was a decline in other land types. In the agricultural land, arable land, woodland and grassland showed a downward trend, and the dynamic degree of pasture was largest, which was related to the dwindling area of grassland. The arable land was also shrinking, and the dynamic degree of change was large. In the category of construction land, the dynamic degree of transportation land was high, approaching 7.1%, indicating that the transportation network continued to improve in Guangzhou City. In the category of unused land, the unused land area declined during 1996 – 2012, indicating that Guangzhou further developed and utilized land to a certain extent.

4 Analysis of spatial structure of land use in Guangzhou City

From the spatial distribution of land use in Guangzhou City in 2005 (Table 2), it can be found that there were obvious regional differences in the spatial distribution of land use type in Guangzhou City. The arable land was concentrated, and the area of arable land in Zengcheng, Conghua and Panyu accounted for 73.75% of total arable land in the city (Table 2). Similarly, garden plot and woodland occupied a large proportion in Conghua and Zengcheng, accounting for more than 65% of garden plot in the city. Due to fast economic development and urbanization in Guangzhou, the proportion of the land for residential, industrial and mining use continued to rise. The proportion of land for residential, industrial and mining use and transportation land was high in Baiyun, Panyu and Zengcheng, and irrigation works land was concentrated in Zengcheng, Conghua and Panyu[33]. From the spatial distribution of land use in Guangzhou in 2012 (Table 2), it can be found that there were obvious regional differences in the spatial distribution of land use types in Guangzhou City. The administrative division of Guangzhou was adjusted twice during 1996 – 2012, and the adjusted administrative region included 10 districts (Liwan, Luogang, Panyu, Huadu, Yuexiu, Haizhu, Baiyun, Huangpu and Tianhe) and 2 cities (Zengcheng and Conghua)[33]. The area in some regions varies, and the horizontal comparison would produce a certain error, so this study lays greater emphasis on the horizontal comparison of the same year when analyzing the spatial structure of land use in Guangzhou. We can see that 76.14% of arable land in the city was concentrated in Luogang, Conghua, Zengcheng and Huadu, and the proportion decreased slightly when compared with 2005. The proportion of the land for residential, industrial and mining use and transportation land continued to increase. In various districts, the proportion of agricultural land declined, while the proportion of construction land, especially the land for residential, industrial and mining use increased.

5 Analysis of driving forces

Land use change, the result of many factors, reflects change in human and natural environment and socio-economic development[34]. In order to make the analysis of driving forces more comprehensive and thorough, this paper compares Guangzhou with other developed cities such as Beijing, Shanghai and Shenzhen. It can be found that the satellite city construction causes great land use changes in Beijing, and makes construction land substantially increase[35]; an important reason for land use change in Shanghai is the rapid development of the economy which leads to changes in land use patterns, and migrant labor and policies are of great sig-

nificance to its development[36-37].

5.1 Economic factors The analysis of driving forces for urban expansion at home and abroad suggests that population growth and socio-economic development, are the major drivers of urban sprawl[38]. The main influencing factors are economic development and social progress, and the rapid urbanization and industrialization have resulted in the restructuring and development of relevant industries[39]. Fig. 2 shows that Guangzhou's GDP rose steadily and rapidly during 1996 – 2012. The unit GDP rapidly increased from 146.806 billion yuan in 1996 to 249.274 billion yuan in 2000; the unit GDP reached 1355.121 billion yuan in 2012, 9 times the GDP of Guangzhou in 1996. Meanwhile, affected by "development craze" and "real estate craze", the changes in various types of land have been accelerated[40].

Table 2 The proportion of land use types in Guangzhou in 2005 and 2012

Unit: %

Year	Administrative region	Arable land	Garden plot	Woodland	Grassland	Land for residential, industrial and mining use	Transportation land	Irrigation works land
2005	Liwan District	0.01	0.01	0.00	0.59	1.49	1.13	0.08
	Yuexiu District	0.54	0.00	0.03	0.30	1.00	0.72	0.09
	Haizhu District	0.30	1.01	0.02	1.19	6.29	3.97	0.42
	Tianhe District	0.70	0.50	1.09	51.64	9.07	6.10	0.52
	Dongshan District	0.56	0.95	0.67	0.33	6.78	7.43	0.11
	Fangcun District	0.10	0.73	0.00	1.96	2.57	1.38	0.50
	Baiyun District	12.03	11.52	9.46	16.70	18.79	26.23	11.62
	Huangpu District	0.66	0.95	0.40	4.52	6.85	3.54	0.74
	Panyu District	17.90	18.14	1.94	15.07	24.11	19.05	16.95
	Huadu District	11.84	11.08	13.89	0.92	9.12	19.52	19.34
	Zengcheng City	39.50	18.68	28.76	1.93	13.35	8.25	20.51
	Conghua City	16.35	37.36	44.40	5.18	7.36	10.11	29.24
2012	Liwan District	0.54	0.12	0.00	0.55	2.91	2.48	1.81
	Yuexiu District	0.00	0.00	0.02	0.00	21.90	0.37	0.49
	Haizhu District	0.39	0.82	0.02	1.31	4.12	3.17	4.17
	Tianhe District	0.67	0.25	0.99	5.69	6.50	1.82	1.03
	Baiyun District	11.28	4.56	5.87	20.19	15.63	18.89	5.18
	Huangpu District	0.66	0.41	0.49	2.05	3.17	3.01	3.65
	Panyu District	20.65	2.60	1.28	19.43	18.66	18.55	27.47
	Huadu District	12.37	9.48	13.80	12.22	13.77	0.99	3.07
	Luogang District	33.31	5.25	6.13	5.14	6.87	10.85	1.65
	Nansha District	7.27	4.29	0.65	4.13	5.27	13.98	34.05
	Zengcheng City	26.72	30.44	25.80	22.93	12.82	17.56	11.26
	Conghua City	16.11	41.76	44.94	6.36	8.08	8.33	6.16

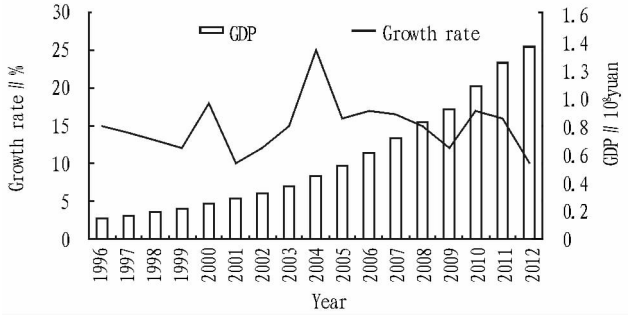

Fig. 2 The changes in Guangzhou's GDP during 1996 – 2012

In order to better reflect the relationship between GDP and land use, this paper uses the change in economic density of land for analysis. The economic density of land is the ratio of annual GDP in one region to land area in the region[41]. By land economic density calculation, we can measure the economic benefits of regional land to provide more guidance and help for regional development. Using the following equation (2), we can calculate the regional economic density of land:

$$P = \frac{G}{L} \quad (2)$$

where P is economic density of land; G is GDP of this region; L is the total land area in this region.

To better understand the changes in economic density of land, here we use formula (3) to better reflect the annual changes in land density in one region.

$$P_n = \frac{P_m - P_{m-1}}{P_m} \times 100\% \quad (3)$$

where P_m is the economic density of land in year m; P_{m-1} is the economic density of land in year $m-1$; P_n is the rate of annual changes in economic density of land.

By calculation, we can get the change in economic density of land during 2006 – 2012 after the administrative adjustment of Guangzhou (Table 3). According to the theory of Kuznets curve,

the change in economic density of land is correlated with inverted U-shaped Kuznets curve. In the city's economic development, the change in economic density of land is increased with the economic development, but when it reaches a certain level, it begins to decrease and shows gradual improvement after the first deterioration. From Table 3, we can see that during 2006 – 2012, the rate of change in economic density of land in Guangzhou first slowly rose and then gently decreased (upper part of inverted U-shaped curve), and it showed the variation similar to inverted Kuznets U-shaped curve[42]. We can see that the economic density of land significantly increases at a certain stage while Guangzhou's urbanization is accelerating. Overall, with Guangzhou's economic development and urban construction, the economic density of land will gradually rise and show a high level, but a series of problems also attract the attention of relevant departments. The land use change in Guangzhou City is restricted by economic factors, and the land use will further change with economic development and urban upgrading in Guangzhou, reflecting the close relationship between land use and economic development.

Table 3 The rate of change in economic density of land in Guangzhou City during 2006 – 2012 Unit: %

Administrative region	2006	2007	2008	2009	2010	2011	2012
Liwan District	10.56	10.36	9.41	10.21	14.84	15.06	15.43
Yuexiu District	14.37	9.53	1.23	6.31	10.11	11.30	12.42
Haizhu District	7.89	17.89	2.24	3.43	27.32	24.52	26.18
Tianhe District	25.55	15.12	10.81	12.26	14.31	14.97	15.35
Baiyun District	9.98	14.67	8.16	10.79	13.87	14.51	15.32
Huangpu District	14.75	10.94	3.32	2.31	12.30	12.53	12.87
Panyu District	13.87	13.10	15.77	17.81	14.95	15.68	16.32
Huadu District	16.54	15.01	5.64	9.34	11.20	12.01	12.76
Nansha District	38.01	31.36	7.05	9.16	16.56	19.33	21.46
Luogang District	21.33	14.98	13.77	4.45	7.26	8.56	9.32
Zengcheng City	13.04	21.58	6.28	6.94	20.05	18.11	18.54
Conghua City	8.46	15.76	9.98	10.46	18.52	17.56	18.98

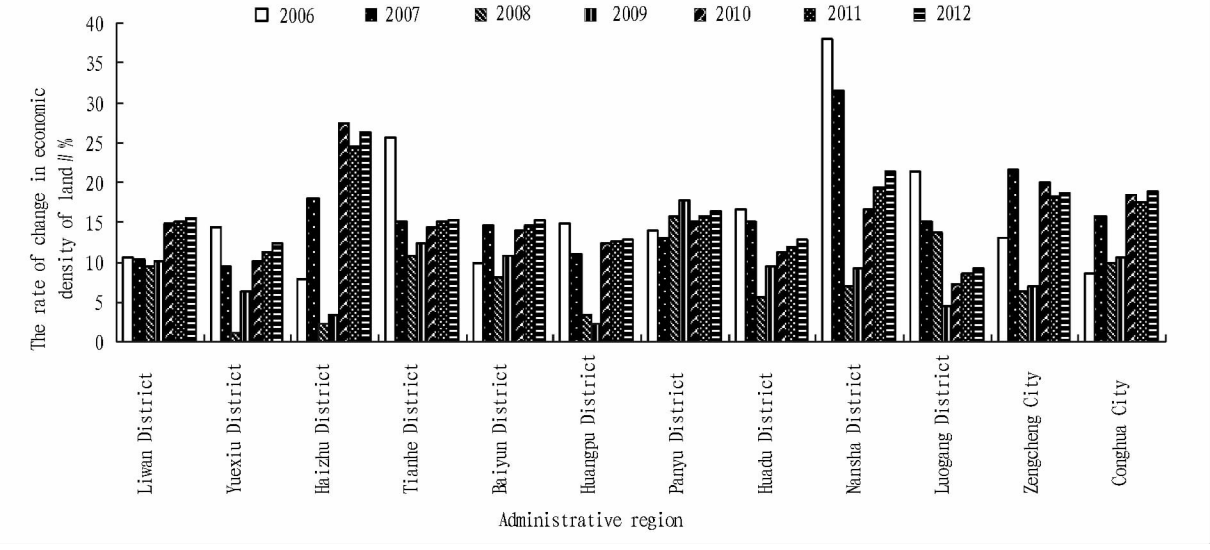

Fig. 3 The rate of change in economic density of land during 2006 – 2012

5.2 Demographic factors As an important part of the urban spatial structure, the urban population and its distribution changes will affect the economic development and people's living standards in Guangzhou City[43-44]. The study on spatial distribution of population density can reflect the level of economic development in one region, so the study on urban land use density has received much attention[45]. With the deepening of reform and opening up and geographical advantages in Guangzhou City, it has attracted a large population, and the population has grown rapidly since 1996. The total household population increased from 6560508 in 1996 to 8222969 in 2012. It can be seen from Table 4 that during 2000 – 2012, the population density rose in Guangzhou, from 942 persons/km^2 in 2000 to 1106 persons/km^2 in 2012 (Fig. 4). The rate of change was greatest in Tianhe District (after administrative adjustment), reaching 68%, from 6433 persons/km^2 in 2005 to 10812 persons/km^2 in 2012. Population growth will inevitably lead to the increase of housing and transportation land. When land area remains unchanged, the increase in construction land will cause reduction of other land, and make the land on the fringe of city change into urban construction land. The increase in population

makes land use density increase, and the land use patterns will also change, having a profound effect on land use change and urban space layout of the entire city[46]. Thus, demographic factors also caused great land use changes in Guangzhou City during this period[47].

Table 4 Population density in Guangzhou City during 2000 – 2012

Unit: persons/km²

Administrative region	2000	2001	2002	2003	2004	Administrative region	2005	2006	2007	2008	2009	2010	2011
Entire city	942	959	969	975	992	Entire city	1010	1023	1040	1055	1069	1084	1096
Dongshan District	34802	35552	36505	37164	37924	Luogang District	416	426	436	448	465	481	498
Liwan District	43645	43580	44213	32116	31983	Liwan District	11924	11933	11925	11948	11954	12002	12021
Yuexiu District	48576	48244	47944	47389	46831	Yuexiu District	34041	34067	34272	34417	34524	34607	34665
Haizhu District	8900	9096	9186	9288	9451	Haizhu District	9702	9851	10043	10211	10368	10540	10702
Tianhe District	5056	5381	5525	5574	5824	Tianhe District	6433	6700	7163	7439	7737	8000	8150
Fangcun District	4212	4270	4336	4352	4405	Nansha District	270	280	282	285	289	292	297
Baiyun District	823	834	823	839	843	Baiyun District	956	965	976	993	1013	1045	1064
Huangpu District	1669	1711	1722	1733	1761	Huangpu District	2119	2129	2149	2167	2183	2196	2215
Panyu District	705	719	733	743	783	Panyu District	1184	1205	1240	1258	1271	1277	1283
Huadu District	626	630	644	640	648	Huadu District	650	656	659	666	672	682	690
Zengcheng City	466	474	479	479	483	Zengcheng City	491	501	506	511	516	520	523
Conghua City	268	269	270	271	271	Conghua City	273	275	278	282	287	293	297

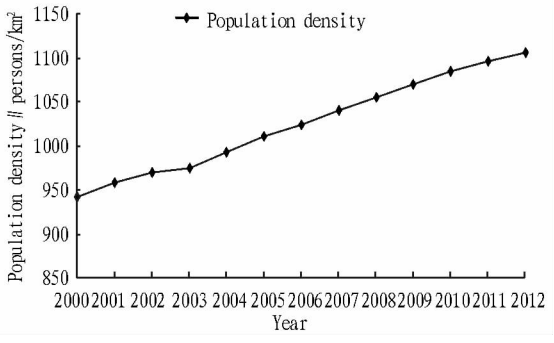

Fig. 4 Changes in population density in Guangzhou City during 2000 – 2012

5.3 Terrain factors The terrain is high in northeast but low in southwest of Guangzhou City, so Zengcheng and Conghua in northeast have a lot of woodland. Tianhe District, Yuexiu District and Liwan District with developed economy are in the central flat terrain, which is suitable for urban expansion and development. In the districts with developed economy such as Yuexiu, Tianhe and Haizhu, the construction land elevation is low and the terrain is relatively flat. Zengcheng, Conghua and Huadu are in the north of Guangzhou, with high terrain, showing that topography has a certain impact on Guangzhou's land use patterns. During 1996 – 2000, the city first expanded in the northwestern plain, and a lot of agricultural land was changed into construction land. After 2000, the direction of expansion of construction land shifted from northwestern plains to southeastern hills, and the land use patterns changed in southeast, indicating that terrain factors have a significant impact on land use development and change in Guangzhou City.

5.4 Policy factors Land use change is often closely related to government policies and requirements[48]. In *Pearl River Delta Reform and Development Plan*, it points out that it is necessary to develop and utilize land resources through scientific and rational approach to improve land use efficiency and utilization value[49]. *National Urban System Plan* (2005 – 2020) points out that it is necessary to take Guangzhou City as the core of Pearl River Delta city cluster, enhance the overall function of Guangzhou City, strengthen regional competitiveness and optimize the spatial structure to promote the development of Pan-Pearl-River-Delta[50]. Guangzhou needs to improve land use, in order to better adapt to the new time requirements[50]. There is also a need to protect land resources and constantly optimize the land use structure while developing economy to promote the sustainable development of land use in Guangzhou[51].

6 Conclusions and recommendations

6.1 Conclusions With the socio-economic development and urbanization improvement, there were dramatic changes in land use types in Guangzhou City during 1996 – 2012[52]. In this period, construction land showed an increasing trend; affected by increase in construction land, agricultural land decreased, and especially the reduction of arable land was particularly evident; woodland always decreased while garden plot and waters increased slightly; there were significant fluctuations in unused land during the study period. During 1996 – 2012, arable land, woodland, grassland, irrigation works land and unused land decreased by 34.6%, 9.4%, 45.1%, 24.9% and 78.9%, respectively; garden plot, other agricultural land, land for residential, industrial and mining use and transportation land increased by 27.4%, 86.1%, 46.7% and 62.8%, respectively. Economic factors and policy factors are the most important factors driving the change of land use in Guangzhou, and economic development and population increase have a significant impact on land use change in Guangzhou City[53].

6.2 Recommendations

6.2.1 Strengthening urban and rural coordination and steadily pushing forward the rural construction land consolidation. It is necessary to coordinate urban and rural development and promote the sustainable use of land resources in Guangzhou. There is a

need to rationally use a variety of urban and rural land resources, strengthen rural land consolidation, integrate resources and funds, promote intensive land use, and improve farmers' production and living conditions.

6.2.2 Strengthening the protection of arable land and farmland quality construction. In the process of vigorously promoting urban construction in Guangzhou City, many problems have occurred such as sharp decrease in the quantity and quality of arable land. Therefore, there is a need to better enhance protection and management of arable land and farmland quality construction, so that the quantity and quality of arable land can be maintained at a certain level. It is necessary to protect high-quality arable land, to promote the sustainable development of land use in Guangzhou City.

6.2.3 Improving the intensive and economical use of construction land. In the urbanization process, a lot of agricultural land and unused land transforms into construction land, leading to uncoordinated land use. Therefore, increasing the intensive and economical use level of construction land helps to improve the efficiency of land use, save land, effectively solve conflicts between increasing construction land and other land, and improve the overall quality of land use.

6.2.4 Establishing land use management system and improving the regulatory mechanism. There is a need to establish a sound land use management system, better improve the regulatory system, and strengthen overall management of land resources and land use. Meanwhile, it is necessary to strengthen strict scrutiny and oversight on standards, approval procedures, implementation, acceptance criteria and project materials of land development and consolidation project, to improve scientificity of land use management system.

References

[1] LIU CW, LI XB. Regional differences in the changes of the agricultural land use in China during 1980 – 2002[J]. Acta Geographica Sinica, 2006, 61(2): 139 – 145. (in Chinese).

[2] Mooney HA, Duraiappah A, Larigauderie A. Evolution of natural and social science interactions in global change research programs[J]. PNAS, 2013, 110(Suppl 1): 3665 – 3672.

[3] Sterling SM, Ducharne A, Polcher J. The impact of global land-cover change on the terrestrial water cycle[J]. Nature Climate Change, 2012, 3(4): 385 – 390.

[4] Geist HJ, Lambin EF. What drives tropical deforestation[R]. Belgium: LUCC International Project Office, 2001.

[5] Foley JA, DeFries R, Asner GP, *et al*. Global consequencesof land use [J]. Science, 2005, 309(5734): 570 – 574.

[6] Lambin E F, Baulies X, Bockstael N, *et al*. Land-use and land-cover change (LUCC): Implementation strategy. A core project of the International Geospere-Biosphere Programme and the International Human Dimensions Programme on Global Environmental Change[R]. IGBP Report 48. IHDP Report 10. IGBP, 1995, Stockholm, 125.

[7] LAI HF, CHEN FG. Trends and driving mechanism of land use change in Guangzhou[J]. Tropical Geography, 2008, 25(8): 455 – 460. (in Chinese).

[8] LI XB. Research priorities for land use change in the accelerated phase of urbanization[J]. China Polulation. Resources and Environment, 2009, 19(5): 1 – 5. (in Chinese).

[9] WANG JY, LIU YS. Land use and land cover change and its driving forces in Sanya[J]. Journal of Natural Resources, 2009, 24(8): 1458 – 1466. (in Chinese).

[10] LIU JY, XU XL, XU XL, *et al*. Spatial patterns and driving forces of land use change in China in the early 21st century[J]. Acta Geographica Sinica, 2009, 64(12): 1411 – 1420. (in Chinese).

[11] ZHANG C, WU KN, CHEN T, *et al*. Land use changes and its driving forces in Zhejiang Province[J]. Resources & Industries, 2010, 12(4): 14 – 18. (in Chinese).

[12] Francesco Geri, Valerio Amici, Duccio, *et al*. Human activity impact on the heterogeneity of a Mediterranean landscape[J]. Applied Geography, 2010, 30(3): 370 – 379.

[13] LUO Y, YANG ST, LIU XY, *et al*. Land use change in the reach from Hekouzhen to Tongguan of the Yellow River during 1998 – 2010[J]. Acta Geographica Sinica, 2014, 69(1): 42 – 53. (in Chinese).

[14] ZENG J, LIU YH, WU DF. Effects of land use change on net carbon emissions in Guangzhou[J]. Guangdong Agricultural Sciences, 2013, 40(6): 186 – 189. (in Chinese).

[15] GAO ZQ, YI W. Land use change in China and analysis of its driving forces using CLUE-S and Dinamica EGO model[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(16): 208 – 215. (in Chinese).

[16] GONG JZ, LIU YS, ZHANG L. The optimal allocation of land use and its potential appraisal in Guangzhou City[J]. Acta Geographica Sinica, 2010, 65(11): 1391 – 1400. (in Chinese).

[17] GUO GH, CHEN YB, GONG JZ, *et al*. Temporal-spatial grading diversification of landscape pattern of urban-rural ecotone in Guangzhou[J]. Tropical Geography, 2010, 30(6): 609 – 614. (in Chinese).

[18] FANG XQ, REN LL, LI QF. The detection and analysis of land use change in the Laoha River Basin during the past four decades[[J]. Remote Sensing for Land & Resources, 2012(2): 125 – 131. (in Chinese).

[19] LIAO JW, ZHOU YZ, JIANG Y. Study on the interaction of land-ocean in coastal Zzone based on LUCC[J]. Economic Geography, 2012, 32(9): 138 – 142. (in Chinese).

[20] YE X, PEI L. Research of land use change based on CA model[J]. Geomatics & Spatial Information Technology, 2013, 36(9): 56 – 61. (in Chinese).

[21] CHEN MH, CHEN YB, GUO GH, *et al*. Dynamic change of land use structure fractal characteristics of urban fringe: A case study in the extend south area of Guangzhou[J]. Geo-information Science, 2011, 13(4): 520 – 525. (in Chinese).

[22] SU CH, FU BJ, LU YH, *et al*. Land use change and anthropogenic driving force: A case study in Yanhe River Basin[J]. Chinese Geographical Science, 2011, 21(5): 587 – 599.

[23] ZHANG K, YU Z, LI X, *et al*. Land use change and land degradationin China from 1991 to 2001[J]. Land Degradation and Development, 2007(18): 209 – 219.

[24] ZHANG L, YANG GF, LIU JP. The dynamic changes and hot spots of land use in Fushun City from 1986 to 2012[J]. Scientia Geographica Sinica, 2014, 34(2): 185 – 191. (in Chinese).

[25] ZHANG L. Analysis of land use change and its changing trend in Haihe Basin[D]. Tianjin: Tianjin University, 2009. (in Chinese).

[26] GAO XY. The optimal configuration of land utilization based on multi-objective ant-genetic algorithms[D]. Wuhan: Wuhan University, 2010. (in Chinese).

[27] CHEN XZ, WANG B, DING ZM. Dynamic evolution analysis on land use structure in Bijie Prefecture[J]. Journal of Anhui Agricultural Sciences, 2008, 36(27): 11886 – 11889. (in Chinese).

[28] ZHOU Y, WU K, TIAN D, *et al*. Dynamic change analyzed of land use in typical Karst Region[J]. Journal of Anhui Agricultural Sciences, 2008, 36(9): 3809 – 3813. (in Chinese).

[29] LUO JW, WANG XY, XIA B. Study on land utilization dynamic changes of Shaoguan City[J]. Journal of Anhui Agricultural Sciences, 2008, 36(33): 14693 – 14695. (in Chinese).

[30] JING PY, ZHANG SW, KUANG WH. Study on land cover/land use change and eco-environment effects of Naiman Banner since 1976s[J]. Journal of Arid Land Resources and Environment, 2008, 22(3): 20 – 25. (in

Chinese).
[31] CHENG P. Research on simulation of land use spatial pattern in Bayan County[D]. Harbin: Northeast Agricultural University,2009: 1 -57. (in Chinese).
[32] XIN FY. Development of land use and ecological environment construction assistant decision-making information system based on ArcEngine[D]. Tai'an:Shandong Agricultural University,2007,1 -90. (in Chinese).
[33] PAN WN. The study on spatial pattern of land utilization density in Guangzhou[D]. Guangzhou: Guangzhou University,2008: 1 -81. (in Chinese).
[34] YANG ZX, CHEN RR, LIU Y, *et al*. Analysis of land use and land cover changes in different economic zones of Chongqing[J]. Journal of Southwest Agricultural University, 2002, 24(6):555 -562. (in Chinese).
[35] MU FY, ZHANG ZX, LIU B, *et al*. Remote sensed monitoring of land use change in Beijing based on TM images and "Beijing -1"[J]. Ecology and Environmnet, 2007,16(1):94 -101. (in Chinese).
[36] HONG J, JIANG N, YU XY. An analysis of land use change and driving force--A case study of Shanghai City[J]. Remote Sensing for Land & Resources, 2002(3): 58 -61. (in Chinese).
[37] SHI LJ, WANG SY, YAO XJ. Spatial and temporal variation characteristics of land use and its driving force in Shanghai City from 1994 to 2006 [J]. Resources and Environment in the Yangtza Basin, 2012, 21(12): 1468 -1479. (in Chinese).
[38] BAO JY, WANG HH. Land use temporal-spatial dynamic change and driving factor analysis of Yizhuang New City area[J]. Science Technology and Engineering, 2008,8(6):1522 -1529. (in Chinese).
[39] QIAO YL, YU SL. Remote sensing dynamic monitoring and expansion change analysis of urban construction land in Taiyuan City[J]. Meteorological and Environmental Sciences, 2011,34(1):1 -4. (in Chinese).
[40] XI FM, HE HS, HU YM, *et al*. Spatiotemporal pattern of urban growth and its driving forces in urban agglomeration of central Liaoning Province, China[J]. Chinese Journal of Applied Ecology, 2010,21(3):707 -713. (in Chinese).
[41] ZHANG GS, DING ZW, WANG FZ. A study on spatial-temporal variation of economic density of Central China[J]. Economic Geography, 2013,33 (5):15 -23. (in Chinese).
[42] FANG B, WU JF, MENG Y. Discussions about spatial-temporal variation of land economic density in Jiangsu Province[J]. Research of Agricultural Modernization, 2010, 31(6):716 -719. (in Chinese).
[43] CHEN YG. A theoretical proof of Clark's model on spatial distribution density of urban population[J]. Journal of Xinyang Normal University(Natural Science Edition) , 2000,13(2):186 -189. (in Chinese).
[44] YIN J, NAN L. Analysis on the characteristics of urban construction land expansion and its driving force ——Taking the case of Xi'an City[J]. Enterprise Economy, 2013,32(7):150 -153. (in Chinese).
[45] GAO CH, ZHANG J, DAI JF. Study on land use changes and driving forces in Wuhan based on RS and GIS[J]. Territory & Natural Resources Study, 2013(3): 31 -32. (in Chinese).
[46] KONG XS. Study on land use/land cover change and environment security in Wuhan Region[D]. Wuhan: Central China Normal University, 2005: 1 -47. (in Chinese).
[47] HE M. Study on the change and driving mechanism of land use in developed economic regions[D]. Nanjing: Nanjing Agricultural University , 2004: 1 -79. (in Chinese).
[48] WANG ZM, ZHANG B, ZHANG SQ. Analysis on land use change and its driving forces in Jilin Province in recent 20 years[J]. Journal of Arid Land Resources and Environment,2004,18(6):61 -65. (in Chinese).
[49] MA L, DONG XQ. An outline review of reform and development planning of Pearl River Delta during 2008 -2020[J]. Business, 2014(3):58 -59. (in Chinese).
[50] ZHONG ZM, LUO Y, HE B. Thinking on Guangzhou development strategy under the positioning of Chinese national central cities[M]. The Memoir of 2010 China Urban Planning, 2010:1 -10. (in Chinese).
[51] LI S. The research for reasonable structure of industrial land in City[D]. Shanghai: Tongji University, 2008. (in Chinese).
[52] YANG GQ, ZHONG M, LIU H. Study on land use changes and driving forces in Guangzhou City[J]. Journal of Anhui Agricultural Sciences,2012, 40(2):1200 -1202. (in Chinese).
[53] XU CD. Analysis of land use change and its tendency based on GIS & RS in Jintai and Weibin Districts of Baoji City[J]. Agricultural Research in the Arid Areas, 2009, 27(5): 240 -244. (in Chinese).

(From page 32)

[5] HU LL. Land development right[J]. Hebei Law Science,2002,20(2):143 -146. (in Chinese).
[6] LIU GZ. Legal status of land development right in the Chinese system of land rights[J]. Academic Research,2007(4):84 -89. (in Chinese).
[7] Sprankling JG. Understanding property law (2nd)[M]. San Francisco: Lexis Nexis, 2007.
[8] RAN H. The fandamental structure of Anglo -American property law: A comparative perspective[J]. Law Science,2005(11):107 -112. (in Chinese).
[9] SUN XZ. General principles on Chinese real rights law[M]. Beijing: Law Press,2009. (in Chinese).
[10] MA JJ, MEI XY. Historical analysis on property right system and its realistic thinking[J]. Social Sciences in China,1999(1):90 -105. (in Chinese).
[11] DU JS, JIN XM. Study on the operation mechanism of introducing land development right in main functional areas[J]. Academic Journal of Zhongzhou,2012(1):39 -44. (in Chinese).
[12] LIANG HX. Study on property law[M]. Beijing: Law Press,1998. (in Chinese).
[13] Danner JC. TDRs-great idea but questionable value[J]. The Appraisal Journal,1997(4): 133 -142.
[14] Lawson FH, Rudden B. The law of property[M]. Oxford: Clarendon Press,1982.
[15] KE WG, SHI MF. Institutional economics:social order and public policy [M]. HAN ZH(Translator),Beijing: The Commercial Press,2000. (in Chinese).
[16] SHI SK. The real right act[M[. Beijing: China University of Political Science and Law Press,2000. (in Chinese).
[17] ZHANG YA, CHEN Y. Primary exploration on allocation and transfer of land development rights[J]. China Land Science,2005,19(5):10 -14. (in Chinese).
[18] LIU J. Restructure of land ownership[J]. Modern Law Science,2006,28 (3): 64 -73. (in Chinese).
[19] JIN XM, YAO XG. The options between centralization and decentralization in the process of decision-making in farmland conversion[J]. Journal of Public Management,2010, 7(3):10 -20. (in Chinese).
[20] QI J. On the historical origin of the dual land ownership theory[J]. China Land Science,1998,12(3):18 -20, 30. (in Chinese).
[21] ZANG KM, WANG WM. Study on definition of rural land development rights and its application in rural land protection:Institutional innovation on existing land property system[J]. China Land Science,2007,21(3):44 -50. (in Chinese).
[22] SHA WT. On the system of land development rights from China's perspective[D]. Shanghai:East China University of Political Science and Law, 2008. (in Chinese).
[23] Marjolein Spaans, Menno van der Veen, Leonie Janssen-Jansen. The concept of non-financial compensation: What is it, which forms can be distinguished and what can it mean in spatial terms ? [R]. ENHR2007 International Conference Sustainable Urban Areas,2007.
[24] JIANG MA. On the direction of administrative law's development in new century[J]. China Legal Science,2002(1):61 -72. (in Chinese).
[25] JIN XM. Market-oriented reform of administration in incremental construction land quota[J]. China Land Science,2009,23(3):19 -23. (in Chinese).