The Study of Driving Forces of Land Use Transformation in the Pearl River Delta during 1990 to 2010※

Kun Yang, Xiuming Wang[1], Peng Zhao, Xucheng Liu, Yuhuan Zhang

South China Institute of Environmental Sciences, the Ministry of Environmental Protection of PRC, NO. 7 West Street, Yuancun, Guangzhou 510655, China.

wangxiuming@scies.org

Abstract. Based on the land use data of the study area in 1990, 2000 and 2010, the paper tries to analyse the characteristic of land use and cover change (LUCC) in Pearl River Delta and its driving forces as well as the differences of driving forces among Shenzhen, Dongguan and Foshan by adopting the approaches of land use dynamic degree, the land use transition matrix and case studies. The results show that a large amount of farmland and forests have been converted to construction land in the study area, and the synthesize land use dynamic degrees of the study area are 2.3% and 6.2% during 1990-2000 and 2000-2010, respectively. The results also indicate that Zhuhai and Shenzhen have the highest land use dynamic degree among the nine cities of Pearl River Delta during 1990-2000, and Dongguan has the highest land use dynamic degree during 2000-2010. It can be inferred that the transitions from farmland and forest to construction land have been propelled by the local economic development and population growth, and the land use changes in forest and grassland have been driven by natural factors such as slope and elevation.

1. Introduction

LUCC is the most significant forms of human activities influence on the nature. Human activities influence on the LUCC in the different scales, therefore influence on the climate change, the ecosystem evolution, the carbon cycle, the atmospheric environment, and the soil environment. In the perspective of research method, the relevant studies of LUCC and the driving forces are as follows, the regression model between land use transition area and diving forces was used to analyze the difference of factors in different period. Factor analysis or canonical correspondence analysis is used to analyze the relationships between land use transformation and economic and natural factors [4]. Grey system correlation analysis method is used to analyze the driving force of land use transformation and predict the expansion of construction land use [5].

The Great Pearl River Delta located in the longitude between112°22′Eand 115°25′E, latitude between 21°23′N and 24°23′N, including nine cities such as Guangzhou, Foshan, Shenzhen, Zhongshan, Huizhou, Dongguan, Zhuhai, Jiangmen, Zhaoqing, with its catchment area spreading 54764 square kilometers. With 59.98 billion residents, the GDP in Great Pearl River Delta was 67841.85 billion yuan in 2016. The Pearl River Delta urban agglomeration is one of the most dynamic economic zones in the Asian-Pacific region. It is one of the three regions with the most innovative capacity and the strongest comprehensive strength. Since the reform and opening up, the Pearl River Delta region has entered a period of rapid industrialization and urbanization. Land use patterns have undergone rapid changes. The intensity of land development in some areas has become too large, threatening regional ecological security, and the internal development of the region has been unbalanced. The characteristic of land use change and driving factors have been studied to provide reference for urban land management and sustainable development.

2. Research method

2.1 Date resources
The land use data was from the Satellite Center of MEP. The study area was divided into six categories of land use type, including farmland, forest, grassland, water area, construction land and unused land. The raster data (1km × 1km) of population density and GDP were from The National Earth System Science Data Sharing Infrastructure. Elevation and slope data were obtained by DEM image extraction. Others were obtained by analyzing the Euclidean distances in ArcGIS 10.0.

2.2 selection of the driving forces
Land use transformation is influenced by natural factors and human activities. It is a complex evolutionary process. According to related researches [3-11], factors such as population, economy, industrial structure, and policies are the main reason of urban land use transformation. Factors caused the change of land use structure, land use efficiency, and land type in the way of industrial structure succession, major infrastructure construction, urban and rural development policies [3]. Based on the characteristics of the study area, and considering the availability and representativeness of the data, 11 factors such as GDP, population, slope, elevation, distance from major roads, distance from coastline, distance from rivers, distance from major economic zones, distances from cities and towns, distances from major transportation hubs (airports, seaports), distances from major industrial parks, were selected to conduct the canonical correspondence analysis.

2.3 Research Method

2.3.1 Land use transition matrix
The land use transition matrix was used to reflect the transfer direction and amount between different land use types. It was realized by the ArcGIS10.1, Arc Toolbox>Analysis Tools > Overlay>Intersect.

2.3.2 Land use dynamic degree
The single and synthesize land use dynamic degree was used to analyze the transformation rate of land use change. The formula for calculating single land use dynamic(R) is as follows:

$$R=\frac{U_b-U_a}{U_a}\ \frac{1}{T}\ \times 100\%$$

In the formula, U_a is the area of a land use type in the initial stage of monitoring. U_b is the area of the land use type at the end of the monitoring period. T is the monitoring period.

The formula for calculating synthesize land use dynamic(S) is as follows:

$$S=\frac{1}{T}\times\sum_{n=1}^{m}\left(\frac{\Delta S_{i-j}}{S_i}\right)\times 100\%$$

In the formula, S_i is the total area of i type land at the beginning of monitoring. ΔS_{i-j} is the total area of land-use type converted from other land-use types within the period from the beginning of monitoring to the end of monitoring; T is the period.

2.3.3 Canonical correspondence analysis
Sorting methods are widely used to study the relationship between vegetation and environmental factors. This study used the Detrended Correspondence Analysis (DCA) to analyze the length of the

environmental gradient axis firstly. The results showed that the length of environmental gradient axis is greater than 4.0, therefore a non-linear unimodal ordering method is used.

This paper equates the land use transition matrix with the vegetation data matrix and the socio-economic data matrix with the environmental data matrix. It is used to explore the correlation between land use change and socio-economic factors, and draws a biplot map. Specifically, the land use change patches in the two time periods are treated as a (0,1) binary data matrix, where 1 represents the occurrence of a type of land use change, 0 represents no change of this type of land use, and the driving force matrix was constructed by using the spatial analyst tools in the ArcGIS10.0 Canonical correspondence analysis is implemented by CANOCO for Windows 4.5.

3. Analysis of land use transformation

3.1 The direction of land use transformation

From 1990 to 2000, 95.9% of the land types in the study area remained unchanged, and the total area of the converted land was 2186.5km2, accounting for 4.1% of the total area of the study area. The main type of land use conversion is farmland changed to construction land, accounting for 38.3% of the total conversion area, followed by farmland changed to water areas, forest changed to construction land, accounting for 32.8% and 13.2% of the total conversion area, respectively.

From 2000 to 2010, the unchanging land accounted for 94.3% of the study area, and the proportion of converted land area is 5.6%.The main land conversion trajectory were farmland that changed to construction land, followed by forest that changed to construction land, water area that changed to construction land, accounting for 48.6%, 22.3%, and 13.8% of the total area of land conversion, respectively.

3.2 The change rate of land use transformation

From 1990 to 2000, based on the overall situation of the study area, construction land and water areas showed an increasing trend, with dynamic degrees of 4.28% and 1.49%, respectively. Farmland, grassland, unused land, and forest showed a decreasing trend, and the dynamic degree of farmland reached a level of -0.93%.

Among the nine cities, the dynamic degree of construction land in Zhuhai is the highest, with an average annual change rate of 15.6%. This is mainly due to the policy effect of Zhuhai Special Economic Zone during this period. The expansion of built-up areas in Xiangzhou and Doumen areas and the construction of major projects such as Zhuhai Airport caused the rapid growth of construction land. Followed by Zhongshan, Dongguan, Shenzhen and Foshan, the average annual change rate of construction land is about 6.0~8.1%.

In terms of synthesize dynamics, the average annual synthesize dynamic degree in the study area was 2.3%, with significant differences across cities, with Shenzhen, Zhuhai being the highest, reaching around 10%, followed by Zhongshan, Dongguan, Foshan, followed by 3 to 4%, Guangzhou. Jiangmen, Huizhou, and Zhaoqing are relatively low, showing obvious circle characteristics.

From 2000 to 2010, only construction land increased in the whole study area, the average annual change rate was 6.22%, and the farmland, forest, grassland, and water area all showed a decreasing trend. In terms of the nine cities, Zhongshan City has the highest dynamic degree of construction land, with an average annual change rate of 11.7%, mainly due to the expansion of the central urban area and the construction of the Torch Hi-tech Zone, and the construction of a large number of industrial parks around Xiaolan Town in the north. Followed by Dongguan, Foshan, Guangzhou, and Huizhou, the average annual change rate of construction land was about 6.4 to 9.5%. Shenzhen, Zhaoqing and Jiangmen were relatively low.

From 2000 to 2010, the synthesize dynamics in the study area was 6.2%, which was significantly higher than that in the previous period. The average annual synthesize dynamic degree in Dongguan reached 21.7%, which was the highest in the study area, mainly due to the large amount of farmland converted to construction land. Shenzhen, Foshan and Zhongshan were followed by about 10%, Guangzhou, Zhuhai, and Jiangmen. Huizhou and Zhaoqing are relatively low. Except Shenzhen and Zhuhai, the synthesize dynamics of the other cities were significantly higher than that in the previous period.

4. The driving force of land use transformation

4.1 The driving force of land use transformation in the study area

4.1.1 In the period from 1990 to 2000

To study the correlation between land use change and driving forces, the land use data of 1990 and 2000 were intersected to obtain 13 types of land use information, as shown in table2. A total of 3,058 plaques with an area more than 1.0 square kilometer were selected, to composite (0,1) Matrix. Similarly, the land use data of 2000 and 2010 were intersected to obtain 11 main trajectories. A total of 3,239 patches were selected to conduct the CCA analysis.

In the first period, the correlation coefficient between the first and second ordering axis and the driving factor was 0.66 and 0.50, respectively. The first ordinal axis explained 48.4% of the land use change-driving relationship and the two axes explained 76.5% cumulatively. As can be seen from Figure 3, the first axis of the CCA ordinal axis mainly reflects GDP (0.91) and population (0.77), and the second axis mainly reflects slope (0.72). Land use change types can be broadly divided into three groups: Forest lands changed to construction lands, forest changed to farmland, farmland changed to construction land, water area changed to construction land, grassland changed to construction land, and stable construction lands as a group, located in the first quadrant, occurring in the area with higher population and GDP density, and farther away from major roads, coastlines, towns, and transportation hubs. The second group is stable forest land and stable grassland, and is located in the second quadrant. It occurs in higher slopes, higher elevations, and away from rivers and industrial parks. The third group is the stable farmland and stable water area, which occurs in areas far away from the town, coastline, and the main economic zone. The correlation between water area that changed to farmland, farmland that changed to water area and the driving factors are relatively weak.

4.1.2 In the period from 2000 to 2010

As in the previous phase, the first axis mainly reflects GDP (0.90) and population (0.63), and the second-order axis mainly reflects slope (0.62). Similar to 1990-2000, the type of land use change in 2000-2010 is roughly divided into three groups on the ordination map, which are located in the first, second and third quadrants. As a whole, the correlation between the conversion from the other land to construction land and GDP, population is significantly lower than that in 1990-2000, indicating that the driving effect of GDP and population is weakening, probably due to the gradual stabilization of land use in highly urbanized areas.

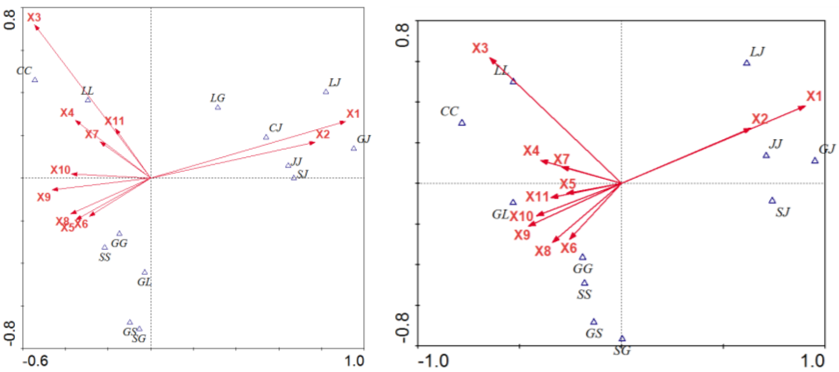

Figure 1. CCA ordinations plot of land use transition types and driving forces at different periods in the study area

Note: X1: GDP, X2: population, X3: slope, X4: elevation, X5: distance from major roads, X6: distance from coastline, X7: distance from rivers, X8: distance from major economic zones, X9: distances from cities and towns, X10: distances from major transportation hubs (airports, seaports), X11: distance from major industrial parks

4.2 The difference of Driving Forces at different periods in typical regions

4.2.1 The driving forces of land use transformation in Dongguan

Land use transformation in Dongguan City in two periods was mainly affected by population, GDP, slope, and elevation. Compared with the two periods, the optimal value on the axis of GDP and population of farmland and forest changed to construction land variables. During 1990 to 2000, it was mainly located in the highest area of the two variables, and in 2000-2010 it was in the higher areas. This is mainly due to the high demand for construction land in the area with highest population and GDP at the previous stage, resulting in the conversion of agricultural and forest land to construction land. In the latter stage, there is no surplus land for development in these areas. In both phases, the conversion of farmland and forest to construction land is located in the area far away from the main economic zone, which is inconsistent with the research assumptions. This is mainly due to the geographical features of the mountainous areas locates in the southern part of Dongguan City and the multiple rivers in the north, making the factor of X8 is negatively correlated with slope (X3), elevation (X4), distance from major rivers (X7), positively correlated with population and GDP. It indicated that the mechanism of land use conversion is that the physical and geographical conditions determine the social-economic pattern to a certain extent. The social and economic factors, together with natural factors and policy factors, impacted the land use conversation process.

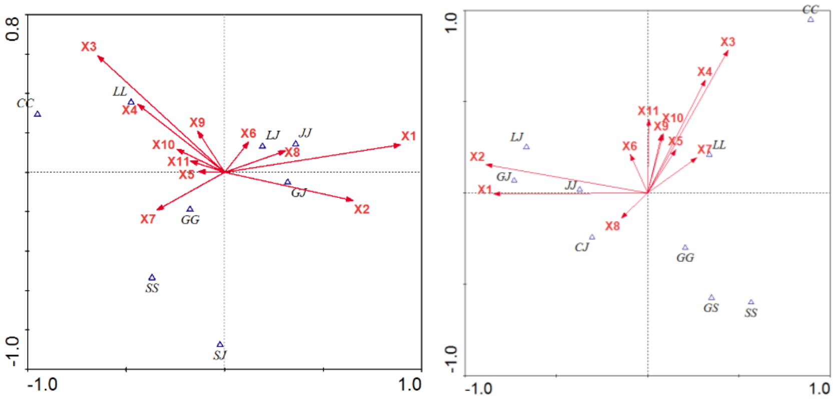

Figure 2. CCA ordinations plot of land use transition types and driving forces at different stages in Dongguan

4.2.2 The driving forces of land use transformation in Foshan

From 1990 to 2000, stable construction land, conversion of water areas to construction land, and conversion of farmland to construction land took place in areas far away from the industrial park, which was inconsistent with the assumptions of this study. The development of industrialization in Foshan is mainly happened in the rural areas, and the data used in this study are parks above the provincial level. Before year of 2000, such parks were mainly located in areas far from the central urban area. Similar to Dongguan, the positions of farmland and water areas converted to construction land in the two stages have changed in the location of population and GDP axis, indicating that the intensity of land development in high-value areas of population and GDP in Foshan City after year of 2000 has been relatively high.

4.2.3 The driving forces of land use transformation in Shenzhen

In two stages, the most suitable values for the transformation of farmland, forest, and water area to construction land in Shenzhen are located in the lower areas of the population and GDP variable axis. This shows that before 2000, Shenzhen has been faced the condition of no surplus land can be used for exploit in the area with high GDP and population. From 1990 to 2000, the conversion of farmland, forest, grassland and water area to construction land all occurred in the area closer to the special economic zone. From 2000 to 2010, except for forest land, the conversion of farmland and water area to construction land occurred at areas away from the special economic zone. This is mainly due to the fact that the land use transformation in this period was mainly affected by the topographic factors, and at the same time, the distance from the special economic zone was significantly negatively related to the elevation factor.

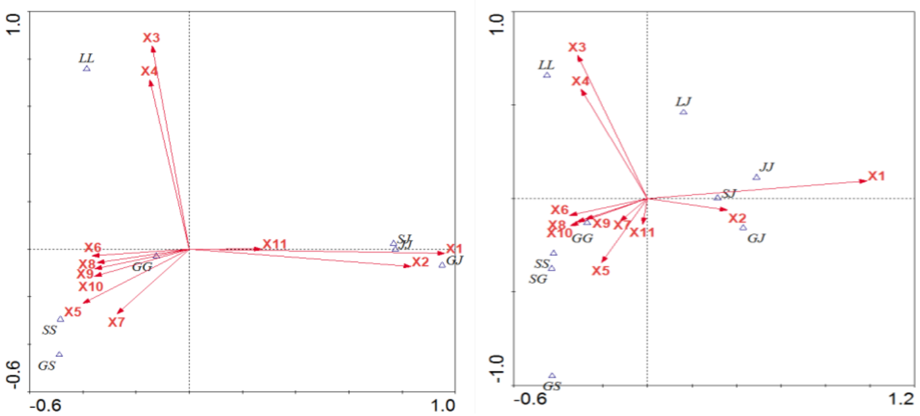

Figure 3. CCA ordinations plot of land use transition types and driving forces at different stages in Foshan

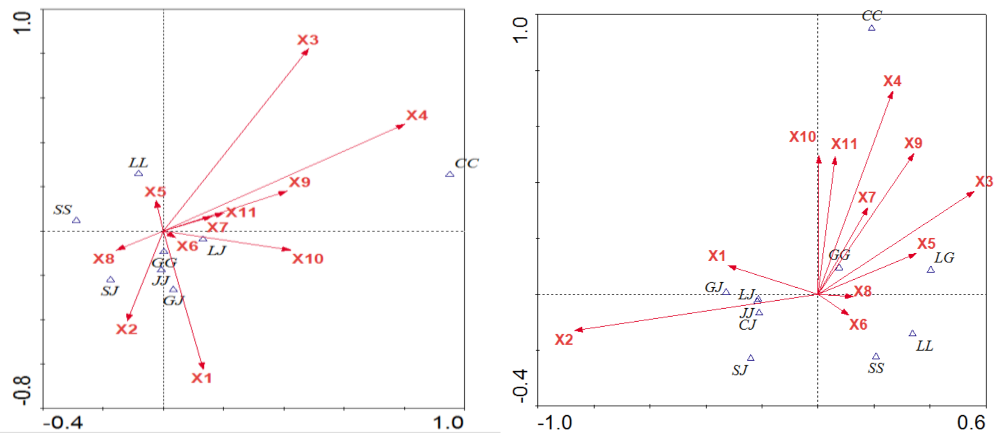

Figure 4. CCA ordinations plot of land use transition types and driving forces at different stages in Shenzhen

5. Conclusion

From 1990 to 2010, the land use transformation in the Pearl River Delta region was mainly reflected in the transformation of farmland and forest to construction land. The synthesize dynamic degree of land use in the two stages of the study area was 2.3% and 6.2%, respectively, and the rate of land use change in the later period was significantly faster. The main source of construction land is farmland, forest land and water area also occupied a certain proportion. In the two phases of the study area, 9.3% and 10.3% of farmland were converted to construction land respectively.

The results of canonical correspondence analysis indicate that GDP, population, and slope are the main drivers of land use change in various periods and regions. From the overall perspective of the study area, unchanged forest land and unchanged grassland mainly located in areas with higher slopes and elevations, and far from rivers. The conversion of farmland, forest land, and water areas to construction land is mainly distributed in regions with high population and GDP, but the driving effect of population and GDP have declined in the latter period.

In order to study the impact of factors such as policy factors, industrialization, and infrastructure construction on land use changes, this study combined with the actual conditions of the study area, increased the factors such as distances from important economic regions, distances from transportation hubs, distances from industrial parks, discussed the difference of driving factors in different regions such as Shenzhen, Foshan and Dongguan. Since human activities are affected by the physical geography, there are correlations between the urban infrastructure construction and geographical factors such as slope, elevation and rivers. Therefore, the mechanism of land use conversion is that the physical and geographical conditions determined the social-economic pattern to a certain extent. The social and economic factors, together with natural factors and policy factors, impacted the land use conversation process.

Acknowledgments
The paper is funded by central level scientific research institute basic research project: study on the evaluation system of the national green development demonstration zone in the Pearl River Delta, and funded by strategic environmental assessment in Pearl River Delta.

References
[1] Xinrong Zhang, Linping Liu, Shi Fang, Wenchao Jiang, Jinchen Wang 2014 *Ecology and Environmental Sciences*, 23(12) 2013-2021
[2] Xiulan Wang, Yuhai Bao 1999 *Progress in Geography*, 18(1) 81-87
[3] Chenxi Li, Kening Wu, Sili Cha 2016 *China Population, Resources and Environment*，26(5) 252-255
[4] Xue Yu, Lijie Pu,Yan Xu, Ming Zhu 2016 *Resources and Environment in the Yangtze Basin*, 25(4) 537-543
[5] Zhaoli Wang, Xiaohong Chen, Lechun Zeng, Qingquan Wei 2006 *China Population, Resources and Environment*, 16(6) 124-128
[6] Huiran Han, Chenfeng Yang, Jinping Song2015 *Economic Geography*, 35(5) 148-197.
[7] Kai Li, Fantang Zeng. 2016 *China Population, Resources and Environment*, 26(5) 252-255
[8] Guangchen Tong, Jie Lin, Hang Chen 2017 *Research of Soil and water conservation*, 24(2) 240-245.
[9] Xiaoming Xu, Ziqiang Du, Hong Zhang, Ling Feng, Xiaoyu Shen 2016 *China Environmental Science*, 36(7)2154~2161.
[10] Chao Tian, Jinze Yang, Boan Shi, Jie Zhang, Rui Qiu, Guanyong Wang, Yaheng Chen 2016 *Chinese Journal of Eco-Agriculture*, 24 (7) 957-968.
[11] Qing Zhou, Zhiming Zhang, Xiaokun Ou, Mingyu Yang 2010 *Acta Ecologica Sinca* ,30(1) 0165-0173
[12] Jiyuan Liu, Wenhui Kuang, Zengxiang Zhang 2014 *Acta Ecologica Sinca*, 69(1) 3-14.