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AN INVESTIGATION OF CHANGES IN CULTIVATED LAND IN GUANGDONG PROVINCE OF CHINA USING GIS

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ABSTRACT: In order to make a thorough investigation about relationship between population increase and cultivated land decrease along with economic development over recent years in Guangdong province, this paper aims to study the relationship between the changes in cultivated land and the rapid economic development in Guangdong Province of China using GIS. The spatial database of administrative boundary in the province is captured and stored in GIS and then several county-based statistics produced by the National Statistical Bureau of China are linked to the spatial data. In the study, the correlation analysis between decrease of cultivated land in some metropolitan counties and population increase is conducted. Besides, similar analysis is carried out between decrease of cultivated land in the Zhujiang (Pearl) River Delta Region and gross industrial output. The result of the analysis is presented in GIS with the boundary data to show the spatial distribution and trend of the phenomenon. Some measures of conserving cultivated land in the province in order to achieve a sustainable development are also proposed.

KEY WORDS: GIS, sustainable development, investigation of cultivated land, Guangdong Province

1 INTRODUCTION

Guangdong Province has been widely known as one of the most important industrial bases for export in China. It has played an important role in economic reform and development in China. In recent years, it has attained a sustainable economic growth and kept the first position in economic league table. However, some vital problems that will directly and indirectly impair sustainable and stable growth in economy in Guangdong Province have been revealed. These problems include rapid increase in population, continuous decrease in cultivated land, abrupt emergence of industrial enterprises, those in small scale in villages. Countless fertile farmlands have become factory buildings. Contradictions between population and cultivated lands are becoming increasingly serious. According to the theory of sustainable development in economy, only by insuring co-ordinated economic increase, a country or a region can be developed healthily. In order to make a thorough investigation about relationship between population increase and cultivated land decrease along with economic development over recent years in Guangdong Province, statistical analysis of major economic data using GIS is carried out. The research results provide some important references for all levels of governments to develop sustainable economy in Guangdong Province.

2 OVERVIEW

GIS is an information system which can store and analyse spatial data. It has analytical tools for geographic research, urban and regional planning, and decision making(Burrough, 1986). GIS generally has the following basic characteristics:

1) It is capable of collecting, managing, analysing and presenting various spatial features and

attributes.

2) It can be used in decision-making process with the aid of spatial analysis and dynamic forecasting.

3) It can be used for spatial query (Aroniff, 1989; Der *et al*., 1995).

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1) The administrative boundary plan in Guangdong Province are digitized and edited in the ARC/INFO; topological relationships between the geographic elements are created and organized.

2) The statistical data for yearbooks in Guangdong Province in China from 1992 to 1996 are input; INFO data files on yearly basis are set up.

3) Statistical techniques are applied in the analysis of attribute data that has been linked with spatial database.

4) Statistical correlation between two kinds of different data is computed by using statistical analysis functions in Excel.

5) Designing the cartographic components of map, map layouts and creating final maps with the aid of cartographic functions in ARC/INFO.

6) Some problems about economic sustainable development in Guangdong Province will be discussed based on the numerical result, and spatial distribution of the phenomenon.

3 METHOD AND PROCEDURE

3.1 Digitizing and Editing of Geographic Data

In order to fully represent spatial information distribution of the phenomenon and enhancing the presentation of the results of statistical analysis on maps, the administrative boundary plan in Guangdong Province (scale 1 ◇4 000 000) is digitized and edited. Different themes are organized in several coverage files (including boundary, stream, administrative place, text and so on). The themes based on geographical features in the coverage files are properly classified and coded. For example, boundaries are classified as provincial boundary, city boundary and county boundary, administrative places are classified as metropolises, cities and counties. Thus different elements on maps can be represented separately. Topological relationship are created in different coverage files based on points, lines and polygons. Therefore, the maps the are ready for use.

3.2 Collection of Statistical Data

For statistical analysis, county-based statistical data of Guangdong Province from 1992 to 1996, produced by National Statistical Bureau of China is used. These statistical data are: population; area of cultivated land; gross industrial output; gross agricultural output and so on (SBGP, 1996). Different years of data are input into relational database and linked with spatial data. The links between records in the feature attribute table and features on the coverage is based on a common key. Table 1, for example, is a table that represents the links between spatial coverage and feature attributes using BOUNDARY-ID item as a key. So, spatial queries and analysis on the data can be performed.

3.3 Modelling and Calculation

In order to understand the real situations about economic development over recent years in Guangdong Province, it is necessary to derive some statistical data such as annual average rate of decrease of cultivated land, annual average rate of increase of population, annual average rate of increase of industry so on. Owing to similar modelling and calculation above, these are illustrated only with an example such as annual average rate of decrease of cultivated land based on county and town from 1993 to 1996.

Mathematical expression for calculating annual average rate of decrease of cultivated land is:

Table 1 Links between spatial coverage and feature attribute

AREA	PERIMETER	...	BOUNDARY-ID
...	...	...	...
12.505	42.933	...	59
3.541	13.252	...	60
2.004	13.077	...	61
0.727	4.367	...	62
.	.	.	.
.	.	.	.
.	.	.	.

BOUNDARY-ID	POPULATION	PLOUGH	...
...	...	...	...
59	79.470	102.710	...
60	58.473	85.630	...
61	129.509	85.301	...
62	119.006	149.251	...
...	...	...	...
...	...	...	...
...	...	...	...

$$\hat{x} = \left(\sum_{i=1}^{n-1} \frac{x_i - x_{i+1}}{x_i} \right) / n$$

where $\hat{x}$ is annual average rate of change of cultivated land, x_{i+1} is cultivated land in current year, x_i is cultivated land in last year, $i = 1, 2, 3, \ldots, n-1$ is number of years. Annual average rate of decrease of cultivated land is calculated from 1993 to 1996 according to cultivated land based on county and town from 1992 to 1996. So, n is 5 in this case. For example, cultivated land in Gaoming City is 1.622×10^4 ha in 1992, 1.425×1^4 ha in 1993, 1.371×10^4 ha in 1994, 1.372×10^4 ha in 1995 1.355×10^4 ha in 1996. The annual average rate of decrease of cultivated land in Gaoming City is 4.3% according to the formula above. It is easier to calculate the rate of change of cultivated land each year from 1993 to 1996 at the same time. A part of the results is shown in Table 2. Negative results mean an increase of cultivated land shown in the region.

Table 2 Annual rate and average rate of change in cultivated land

BOUNDARY-ID	The rate of change in cultivated land				
	1993	1994	1995	1996	Average
...	...	...	...	...	
53	0.122	0.037	-0.001	0.013	0.043
54	0.148	0.120	0.104	-0.075	0.074
55	0.010	0.015	0.000	0.000	0.006
56	0.021	0.015	0.010	-0.003	0.011
57	0.014	0.006	0.006	-0.001	0.006
58	0.013	0.013	0.004	0.001	0.008
59	-0.011	-0.005	-0.013	-0.018	-0.012
60	-0.010	-0.012	-0.004	-0.002	-0.007
61	-0.003	-0.013	0.002	-0.013	-0.007

3.4 Correlation Analysis

In the research, the correlation analysis between decrease of cultivated land in some cities and counties and population increase is conducted. Besides, similar analysis is carried out between decrease of cultivated land in the Pearl River Delta Region and gross industrial output. In order to study the relationships between two or more variables. The equation for the correlation coefficient (Shaw *et al.*, 1994) is:

$$\rho_{xy} = \frac{Cov(X, Y)}{\sigma_x \cdot \sigma_y}$$

where ρ_{xy} is the correlation coefficient. The values of correlation coefficients can lie between + 1 and - 1. These extremes represent respectively the perfect positive or negative relationship between the two vari-

ables. In the former case the values of two variables increase in concert, in the latter the value of one variable increases as the other decreases. A value of 0.0 indicates the complete absence of any correlation between two variables. In this study, negative relationship between two variables is neglected. $Cov(X, Y)$ is covariance between two variables, its mathematics expression is:

$$Cov(X, Y) = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})$$

where σ_x, σ_y are standard deviations of random variables X and Y respectively, their mathematical expressions are as follows:

$$\sigma_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})}; \quad \sigma_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})}$$

The correlation between rate of change of cultivated land and rate of change of population based on county and town in Guangdong Province from 1993 to 1996 is computed and a part of them are shown in Table 3.

Table 3 Correlation between change of cultivated land and change of population

BOUNDARY-ID	YEARS	PLOUGH/R	POPULATION/R	CORRE-COEFFICIENT
...	...	...	...	...
49	1993	0.329	0.060	0.921
	1994	0.178	0.034	
	1995	0.001	-0.039	
	1996	0.284	0.098	
50	1993	0.031	0.023	0.032
	1994	0.038	0.017	
	1995	0.001	0.018	
	1996	0.029	0.015	
51	1993	0.031	0.022	0.665
	1994	0.009	0.021	
	1995	0.000	0.014	
	1996	0.011	0.013	
52	1993	0.169	0.031	0.883
	1994	0.083	0.017	
	1995	0.000	0.017	
	1996	0.013	0.017	
53	1993	0.122	0.023	0.744
	1994	0.037	0.019	
	1995	-0.001	0.008	
	1996	0.013	0.019	
54	1993	0.148	0.032	-0.749
	1994	0.120	0.016	
	1995	0.104	-0.179	
	1996	-0.075	0.256	
...	...	...	...	...

3.5 Presenting the Results of the Analysis

In order to present spatial distributions of the results of the analysis, maps are used. Maps can be composed of various data from the result according to different needs of spatial analysis. Here, some procedures would be shown only by compiling map of annual average rate of decrease in cultivated land in Guangdong Province in China from 1993 to 1996.

First of all, annual average rate of decrease of cultivated land in Guangdong Province are classified according to distribution and characteristics of the available data. Generally speaking, they will be classified into 6 intervals.

Design of the map contents involves the choice of mapping symbols, texts, colour and so on. The symbols are chosen and designed according to different scales (Wu, 1989). Besides, title, key legend, neat-

lines and scale bar are also added to the map composition. Fig. 1 is only an example showing "annual average rate of decrease in cultivated land in Guangdong Province".

4 ANALYSIS AND EVALUATION

Three main observations can be made from Fig. 1.

1) The decrease of cultivated land in most of prefecture-level cities is much quicker than that in small towns and counties, especially Shenzhen, Foshan, Huizhou, Chaozhou and Yunfu. Annual average rates of decrease in cultivated land in these prefecture-level cities exceed 10%.

2) The annual average rates of decrease in cultivated land in the Zhujiang River Delta is much quicker than another else, which exceed 2%;

3) The annual average rate of decrease in cultivated land area in only a few regions including Zhanjiang, Shaoguan and Heyuan is less 1%, of which some have increase trend of cultivated land.

In summary of the above, the results of statistical analysis show that: the more developed the regions in Guangdong Province are, the greater the rate of decrease in cultivated land is; the more population the regions in Guangdong Province have, the greater the rate of decrease in cultivated land is. Correct inferences can be made: if this trend continues, cultivated lands in all prefecture-level cities would have disappeared in 8 – 10 years; the cultivated lands in the Zhujiang River Delta would have disappeared in 15– 20 years. Undoubtedly, the trend of decrease in cultivated land will bring tremendous impact on the sustainable economic development in Guangdong Province. The main causes for the rapid decrease of the cultivated land are believed to be rapid increase in population and industrial production. In order to explain the problem, this research has developed a series of statistical analysis models such as correlation between rate of decrease in cultivated land and rate of increase in population, as well as correlation between rate of decrease in cultivated land and rate of increase in gross industrial output from 1993 to 1996 using GIS. So the statistical analysis results will further confirm the correlation relationship.

Table 4 and Table 5 show the correlation relationship between rate of decrease in cultivated land and rate of increase in population in some metropolitan counties, and the correlation coefficients between rate of decrease in cultivated land and rate of increase in gross industrial output in some regions of the Zhujiang River Delta from 1993 to 1996 respectively.

Table 4 Correlation between plough and population in some prefecture-level cities

	Guangzhou		Shenzhen		Foshan		Huizhou		Shaoguan	
	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase
1993	0.3	1.5	32.3	133.7	32.9	6.2	39.2	7.3	12.9	3.7
1994	9.2	2.1	34.7	14.0	17.8	3.4	– 14.8	5.8	6.2	2.2
1995	3.4	1.3	4.1	10.3	0.1	– 3.9	12.5	4.5	2.9	1.8
1996	3.2	1.2	– 0.5	29.2	28.4	9.8	4.9	2.9	2.2	0.3
Coefficient	0.771		0.823		0.921		0.610		0.920	
	Chaozhou		Zhaoqing		Qingyuan		Maoming		Meizhou	
	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase
1993	19.6	3.1	12.0	7.7	4.5	4.1	3.4	3.4	8.7	5.8
1994	11.6	1.8	16.4	7.0	2.0	2.9	1.6	2.9	7.1	5.8
1995	4.5	2.0	3.3	4.0	0.3	2.3	0.4	2.9	0.8	3.7
1996	7.4	– 1.8	2.2	3.6	– 0.1	1.6	– 0.4	2.7	0.8	3.5
Coefficient	0.634		0.920		0.978		0.949		0.986	

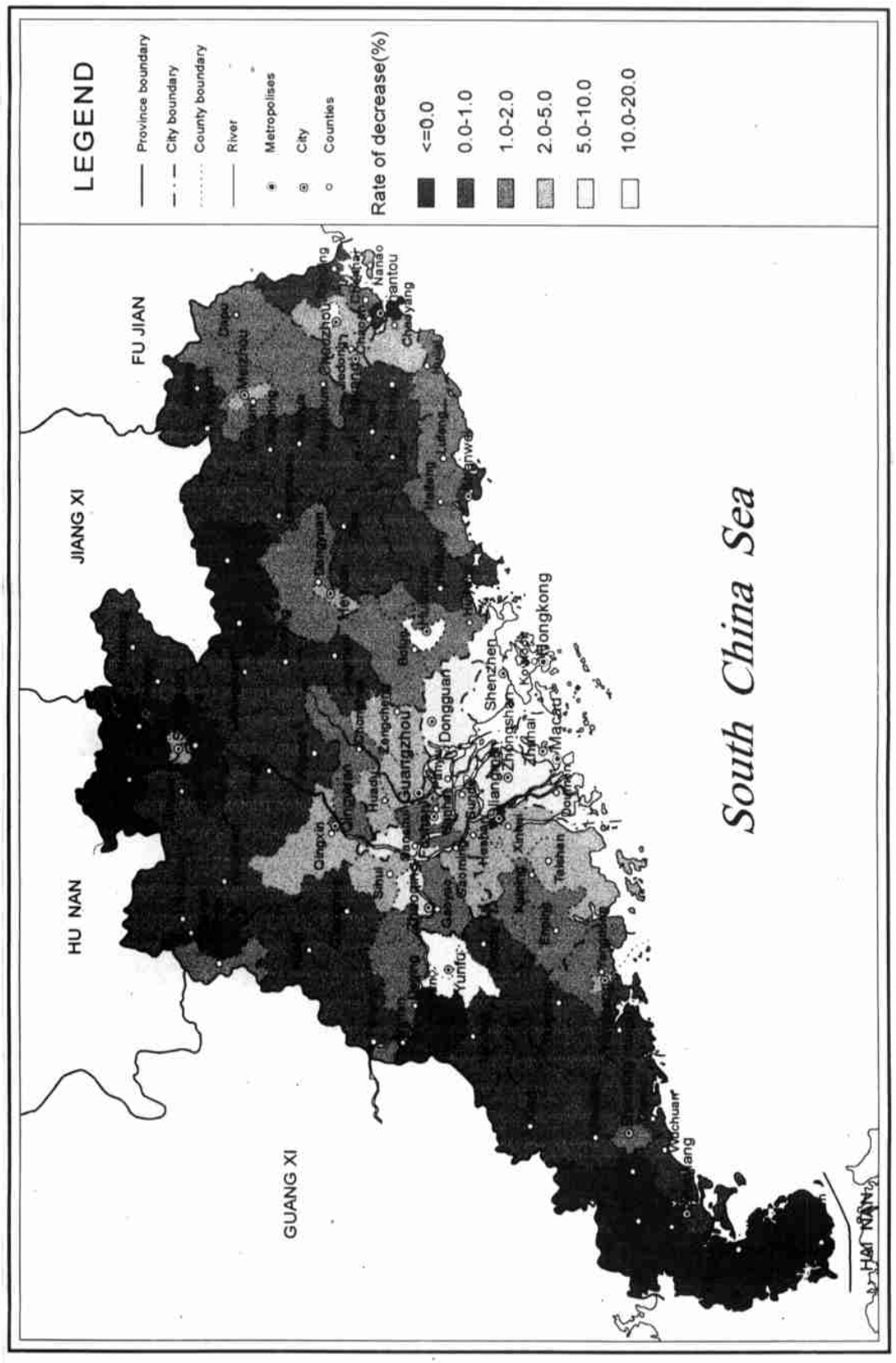

Fig. 1 Annual average rate of decrease in cultivated land in Guangdong Province (1993 – 1996)

Table 5 Correlation between plough and industry output in some regions in the Pearl River Delta(%)

	Zengcheng		Conghua		Shenzhen		Huidong		Taishan	
	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase
1993	5.4	102.0	2.4	40.0	32.3	78.2	2.7	67.8	4.3	70.3
1994	4.7	74.9	2.7	52.8	34.7	38.4	0.1	58.5	3.4	46.6
1995	0.6	3.5	-1.4	5.7	4.1	28.6	0.1	34.8	0.0	25.7
1996	-0.6	57.1	0.4	31.0	-0.5	20.1	0.0	15.3	1.0	39.5
Coefficient	0.734		0.978		0.714		0.976		0.930	
	Xinhui		Gaoming		Shunde		Dongguan		Zhongshan	
	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase	Plough decrease	Population increase
1993	7.8	42.3	12.2	51.4	14.8	47.9	2.1	59.7	11.1	42.3
1994	9.3	31.3	3.7	38.0	12.0	54.4	1.5	36.5	9.2	39.4
1995	0.0	23.1	-0.0	26.2	10.4	30.4	1.0	30.0	2.0	28.6
1996	1.9	11.5	1.3	19.8	-7.5	25.6	-0.3	18.3	1.0	17.7
Coefficient	0.825		0.931		0.773		0.923		0.948	

From Table 4 and Table 5, there are strong correlation relationships between rates of decrease of cultivated land and rates of increase of population in most of the prefecture-level cities in Guangdong Province. There are also correlation relationship between rates of decrease of cultivated land and rates of increase of grass industrial output in the Zhujiang River Delta Region.

In modern cities, land use must be planned and controlled due to rapid increase in population and limited land resources. However, the results of this research indicate that annual decrease of cultivated land is mainly caused by rapid increase in population of prefecture-level cities in Guangdong Province. It can further confirm that "overheat" of development in real estate is one of the major causes for decreasing cultivated land in some prefecture-level cities. The development is at the cost of cultivated land resources. The cultivated land has dropped 8.4% from 1988 to 1996 in Guangdong Province. However, residential and industrial landuse have gone up 40.5%, the most of which are used as residential areas which are distributed mainly over peri-urban areas (NLB). It is quite evident that this model of urban development is not desirable because it radically contravenes sustainable developing theory for urban area. Urban development making use of land resources in urban areas must pay attention to the impact on eco-environment. Abusing cultivated land have to be absolutely forbidden by holding growth of population, industry and various constructions projects in urban areas. Thus the aim of sustainable development for urban areas can come true. In order to prevent the abuse of farmland, all levels of governments have to strengthen the management of real estate and completely prohibit the use of cultivated land for residential purpose. At the same time, removal of the house which have been built without any planning permission and conversion of the land to the original cultivated purpose and good planning of new residential areas are the only ways to ensure balance between urban development and cultivated land.

The Zhujiang River Delta Region is one of the hottest land of economic development in Guangdong Province, even in whole country since the policy of economic reform and opening in 1979. The areas in Zhujiang River Delta Region referred in this paper include Guangzhou area (including Guangzhou City, Huadu, Conghua, Zengcheng and Panyu), Zhongshan City, Jiangmen Area (Jiangmen City, Xinhua, Taishan Kaiping, Enping and Huoshan), Foshan, (including Foshan City, Nanhai, Shunde, Gaoming and Sanshui), Zhaoqing area (including Zhaoqing City, Gaoyao, Sihui), Dongguan city, Huizhou area (including Huizhou City, Huiyang, Bole and Huidong), Zhuhai area (including Zhuhai City and

Doumen) and Shenzhen City. According to the statistics, annual average rate of increase of gross industrial output in Guangdong Province from 1993 to 1996 was 29.9%; the rate of increase of gross industrial output in the Zhujiang River Delta Region was 38.8% in 1993, 31.1% in 1994, 30.6%; in 1995, 26.5% in 1996. Thus it can be seen that the rate of increase of gross industrial output in the Zhujiang River Delta region is not only greater than that in Guangdong Province, but also greater than that in China over recent years. It has exceeded that in Hong Kong, South Korea, Taiwan and Singapore in the initial stage of economic development (SBGP). However, Table 5 and Fig. 1 also show that annual average rate of decrease of cultivated land in the Zhujiang River Delta Region has greatly exceeded anywhere else in Guangdong Province. In fact, good geographic environment and cheap labours in the Zhujiang River Delta Region have attracted large numbers of foreign companies and Sino-Foreign companies to invest and build factories, especially those from Hong Kong and Macau. Small factories and large enterprises founded in the past farming villages and towns have spread vigorously and have become one of the most important bases of manufacturing industry in Guangdong Province, due to the influx of companies to the region. Thus, factory and residential buildings have been built on the original farmlands. According to the statistics, industrial and mining landuse area in 1988 was 6.97% of the total land areas in the Zhujiang River Delta Region, and those in 1996 increased by 11.4%. At the same time, the area of industrial and mining landuse in the region increased twice(73.19%) in Guangdong Province (NLB). Consequently, the average area of cultivated land per capita had been decreased to only 0.0362 ha in the Zhujiang River Delta Region by 1996, which is much lower than the minimum standard of 0.0533 ha set by Food and Agricultural Organization of the United Nations (Lin, 1997). The consequency is the insufficient grain supply in the region. The province has to import food from other provinces, even abroad. Obviously, it is not a good phenomenon to develop industry at the cost of cultivated land. It would be impossible to ensure the sustainable and stable development of economy in the region. All levels of governments have to pay attention to the trend and to strictly control the approval procedures for factory buildings and residential buildings. Abusing cultivated lands for factory buildings and residential buildings in any way and for any reason have to be absolutely prohibited. At the same time, some industrial enterprises which have poor efficiency and pollute environment should be closed. It is also necessary to remove illegal factories and residential buildings and to convent the land to the original cultivated purpose.

Fortunately, Fig. 1 shows that annual average rate of decrease in Zhanjiang, Shaoguan and Heyuan over recent years is less than anywhere else in Guangdong Province. Actually, most of these regions are not "hot spots" of economic development. These regions still maintain the model of economic development based on agriculture. Thus their success in preserving and exploiting areas of cultivated land is much better than anywhere else in Guangdong Province.

5 CONCLUSIONS

Land is a precious resource. More and more people understand the importance of sustainable and stable development of economy (ITPCL, 1997). This paper aims to study the relationship between the changes in cultivated land and the rapid economic development in Guangdong Province in China using GIS. The spatial database of administrative boundary in the province is established in GIS and then several variables of the county based statistics produced by the National Statistical Bureau of China is linked to the spatial data. In this research, the correlation analysis between decrease of cultivated land and population increase in some prefecture-level cities is conducted. Besides, similar analysis is carried out between decrease of cultivated land in the Zhujiang River Delta Region and gross industrial output. The result of the analysis is presented in GIS with the boundary data to show the spatial distribution and trend of the phenomenon. Some measures of saving

cultivated land in the province in order to achieve sustainable development are also proposed.

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