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GIS-BASED ANALYSIS OF URBAN LAND-USE CHANGES
— A Case Study of Haizhu District of Guangzhou City, China

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ABSTRACT: This paper describes a GIS-based spatial analysis method that combines qualitative analysis and quantitative analysis to characterize land-use patterns and predict the trend of future land-use changes in Haizhu District of Guangzhou City, China. Spatial technique is introduced to manage land-use data and derive information of land-use changes. Through the case study for the selected area, it is demonstrated that the method and technique introduced in the paper can be effectively utilized for the analysis of urban land-use changes. Based upon this analysis, the paper also provides discussions and recommendation on urban land-use planning, urban planning and land management. Both land-use maps of Haizhu District of Guangzhou in 1995 and 1997 and the remote sensing images of 1999 are utilized in the current research. It is convenient to get various statistic data and to combine attribute data with spatial data so as to analyze land-use changes in a geographic context, which is especially suitable for the need of urban construction department, urban management department and urban planning department.

KEY WORDS: GIS; land-use; spatial analysis; overlay analysis

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1 INTRODUCTION

Major characteristics of urbanization include: urban construction is continuously spreading, the demand for urban land use is rapidly swelling, and a lot of agricultural land is converting into non-agricultural land. When these characteristics are reflected in urban system, the developing speeds of big cities and super cities are quickening (CHEN, 1999). Based on the condition of market, land resource bears three types of values which are respectively social value, economic value and ecological value. The external expressive form of the interaction of these different values is that the amount of population, economy and land use increases in a given geographic area. Serious problems addressed on sustainable urban development include how to properly make use of limited land resources, how to balance actual land use capacities and theoretic capacities, how to scientifically appraise the benefit of urban land use and how to improve the capacity of urban land use (CHEN and PETER, 2000). A simple survey of land use changes in general is not adequate for a thorough understanding of the conditions and factors of various types of urban land-use changes. Instead detailed analysis of urban land-use patterns, changes of these patterns, and underlying conditions as well as development directions will be necessary (ZHANG *et al.*, 2001). Using GIS, it is convenient to make various statistic data be spatialized and to combine attribute data with spatial data so as to analyze land-use changes in a geographic context, which is especially suitable for the need of urban construction department, urban management department and urban planning department. In a GIS environment, various data of land use and remote sensing images can be effectively manipulated and analyzed, which can form a critical basis for

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land-use studies, particularly in deriving dynamic land use patterns and synthesizing land-use changes (CHEN and PETER, 2000).

2 RESEARCH METHOD

2.1 The Selection of GIS Tools

A commercial GIS system, GeoMedia4.0 from Intergraph, has been selected to manage spatial data and to provide the needed analysis for the current research. The reason for this selection is that the software provides advanced spatial database technology to allow effective integration and analysis of attribute data and spatial data. With the software, data in different format can be easily converted and integrated. Spatial data and attribute data of the same spatial features can be combined after these data are imported into the system. Through overlay analysis, it can combine different categories of spatial and attribute information (e.g. land-use maps and socio-economic data in different times) in the same geographical space, which forms a key ability in the analysis of urban land use.

2.2 The Selection of Study Area

This research selects Haizhu District in Guangzhou City as the study area. There are two major reasons for this choice: 1) Haizhu District is surrounded by the Zhujiang River. Therefore, the study area can be conveniently defined. The selection of such a study area also allows a natural delineation of the research region and can eliminate the influence of unnecessary factors for the analysis. 2) Haizhu District represents a transition zone between city and countryside. With continuous urbanization, land-use changes frequently in this district. Because of that, it can serve as a very good testing case for land-use change studies. Haizhu District includes Haizhu Island, Gongzhou Island in the east and three Yahuansha oases encircled by water. The whole area is 94.25km^2. It is a relatively new region with a fast developing speed.

2.3 Database Development

The database used for this study consists of two parts, which are respectively basic information database and special subject information database. Land-use maps are the core of the basic database. The basic database also includes urban cadastral maps, land-use planning maps and large-scale relief maps. Special subject information database contains two types of information. One is land management information, which covers land construction and land development, the other is statistic information of society and economy, which is related to socio-economic conditions and land quality. The land use represented on the land-use maps can be divided into eight first-grade sub-classes based upon the national classification standard of land use (YAO and SHUAI, 1995). But there are only 28 secondary-grade sub-classes in this district because there are only 28 among 47 secondary-grade sub-classes. The detailed classification is indicated in Table 1.

Table 1 Classified system of land use in Haizhu District

First grade types	Secondary grade types
Cultivated land	Irrigated paddy field, irrigated field, dry land, vegetable plot
Garden land	Orchard, other garden plots
Woodland	Forest land, shrubbery land, pre-forested land, nursery land
Grassland	Artificial grassland
Residential and industrial and mining area	Cities and towns, rural residential area, independent industrial and mineral land, special land
Transportation land	Highways, rural roads, ports and docks
Water area	River surface, pond surface, ditch, shallow-tidal-flat area
Unused land	Barren land, sand land, grassless land, raised path through fields, beach land, others

2.4 Technical Approach

The spatial variation and changes of land-use patterns over time is the focus of the analysis. This analysis is accomplished mainly through using of GeoMidia4.0. To achieve the research objective, GIS functions are either used separately or bundled to form sophisticated analytical capabilities. The general procedure is listed in Fig. 1.

3 CASE ANALYSIS

In the research, land-use maps and satellite images in three time periods (1995, 1997, 1999) are utilized

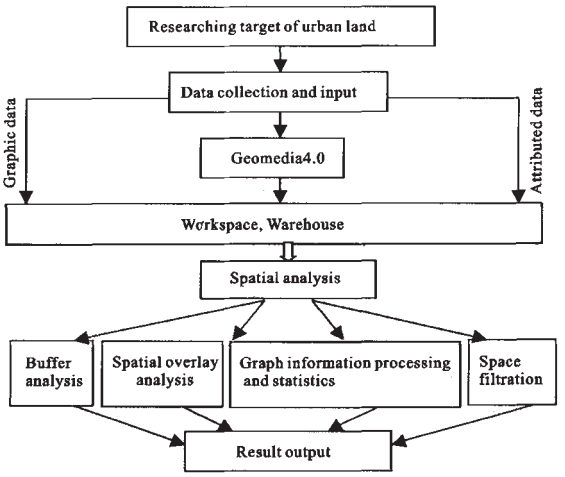

Fig. 1 Technical route of the study

to make regional maps of land-use changes. The land-use data come from Land Management Department of Guangzhou City. These data are obtained from land-use change surveys and provide land-use coverage for both the year 1995 and the year 1997. The data of 1999 are satellite images, annotated with data of land-use change survey of 1999. Land construction and land development data in the past are also utilized in the research.

3.1 Land-use Change Characteristics

Land-use changes are mainly reflected in the changes of land-use types, including changes of spatial patterns and changes of land-use intensity. Changes of land-use patterns can be intuitively observed from land-use maps of two different times (Fig. 2 and Fig. 3). As far as Haizhu District is concerned, with the increase of the population, the development of the economy and the increase of external interactions, each type of land-use shows certain regularity when changes take place. Based on the type of land-use where the change takes place, land-use changes tend to form an outward spreading pattern. In the district, some land-use types, such as urban and cultivated land, have evident changes. Residential area, industrial area, mining area and transportation lands are expanding progressively while cultivated land and garden land are shrinking over time. When detailed land-use changes are analyzed, two types of spatial technique can be utilized to handle two different situations. One is when the area of a land use increases. In this case, a comparison of the data field called From Feature of a later date with the ones called Subtract Feature of an early date can be used to identify the expansion of the land area. The second situation is when the area of a land use decreases. The method to analyze this type of change is a comparison of the above-mentioned data fields in a reverse order. The general change map of land-use is resulted from the ring upon ring overlay of two periods of corresponding layers. It can be visually displayed in maps for the situation of increase and decrease of each land-use type. And at the same time the corresponding attribute characteristics and the related area can be identified and measured. In a detailed land-use map, cultivated land, garden land or cities and towns may be represented with a single category, or with several sub-categories, that is, dry land and irrigated land can be identified as separate categories or merged to form a single category.

To our noteworthiness, in the analysis of land-use changes, underlying geographic factors that play a role

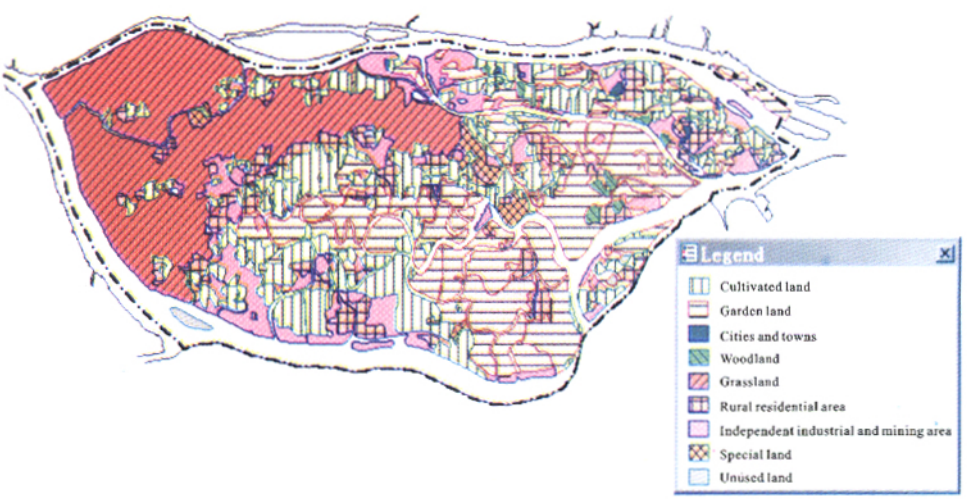

Fig. 2 Present land-use map (1995) in Haizhu District

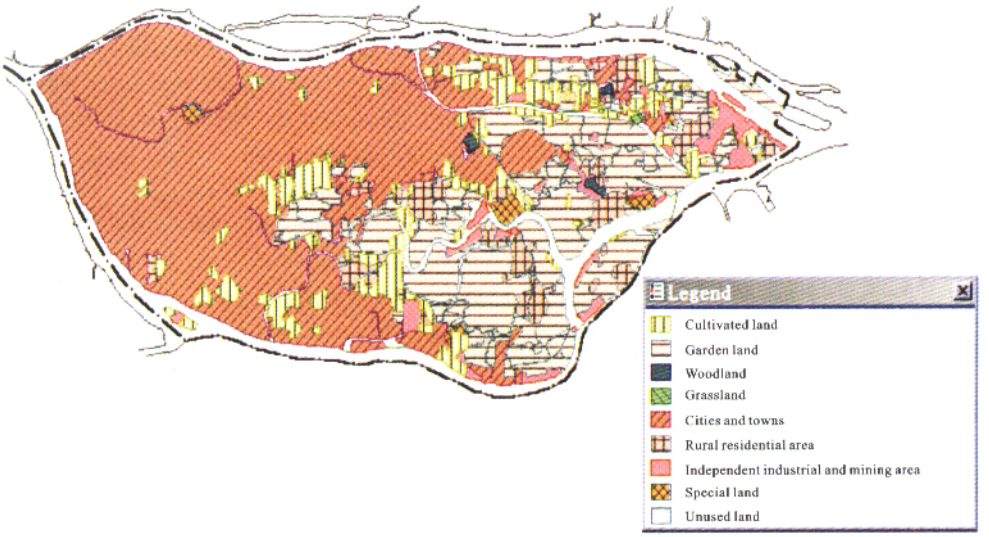

Fig. 3 Present land-use map (1997) in Haizhu District

in these changes need to be analyzed. In order to understand the effect of each of these factors or their comprehensive effect, the use of stratification treatment and synthetic analysis is necessary. The method to handle little polygons resulted from land-use change is to merge them into the adjacent land-use types that are the same or close to the types of land use these polygons represent. Usually, a distance index can be derived from measuring the compatibility of the land-use types between these little polygons and polygons in the neighborhood (PAN and ZHANG, 1999). For example when the area of a little cultivated land parcel is less than 4 – 6mm^2, then it will be merged into dry land or irrigated land that belongs to the same type, but not woodland, which is a different type. This will maintain the consistency between the layer that represents land-use changes and the layer that provides information for identifying these changes and insures that the updated land-use types remain correct.

The area of various landuse types can be calculated through the statistic function of graphic basic information of Geomedia. The corresponding total area of different landuse types is listed in Table 2 (the area of various land-use of 1999 is obtained from the analysis of the remote sensing images). The detailed changes can be identified through overlays of land-use maps of different times(Fig. 4 and Table 3).

A major characteristic of land-use changes in Haizhu District is that agricultural land is decreasing and construction land is increasing. The area of agricultural land has been reduced steadily. In 1995, the agricultural land is 305 746. 13ha; in 1997, 292 075. 63ha; and in 1999, 280 741. 63ha. The ratio of agricultural land to total land area also becomes less and less, from 33. 12% in 1995 to 31. 64% in 1997 and to 30. 42% in 1999. For agricultural land, cultivated land has a greater change, secondly garden land. Construction land has increased steadily. And the ratio of construc-

Table 2 Land-use area (1995, 1997, 1999) in Haizhu District (ha)

Land-use type	1995	1997	1999
Cultivated land	93556. 76	82254. 44	73380. 67
Garden land	205844. 20	203497. 70	201087. 83
Woodland	4342. 17	4342. 17	4290. 81
Grassland	1982. 32	1982. 32	1982. 32
Residential and industrial and mining area	420903. 01	434704. 58	445992. 89
Cities and towns	213905. 57	224737. 65	233844. 20
Rural residential area	63081. 53	63186. 91	63375. 67
Independent industrial and mining area	131915. 26	134761. 35	136754. 34
Special land	12000. 66	12018. 67	12018. 67
Transportation land	8945. 14	10517. 73	11061. 53
Water area	184853. 71	184226. 73	183871. 22
Unused land	2523. 26	1424. 71	1283. 98

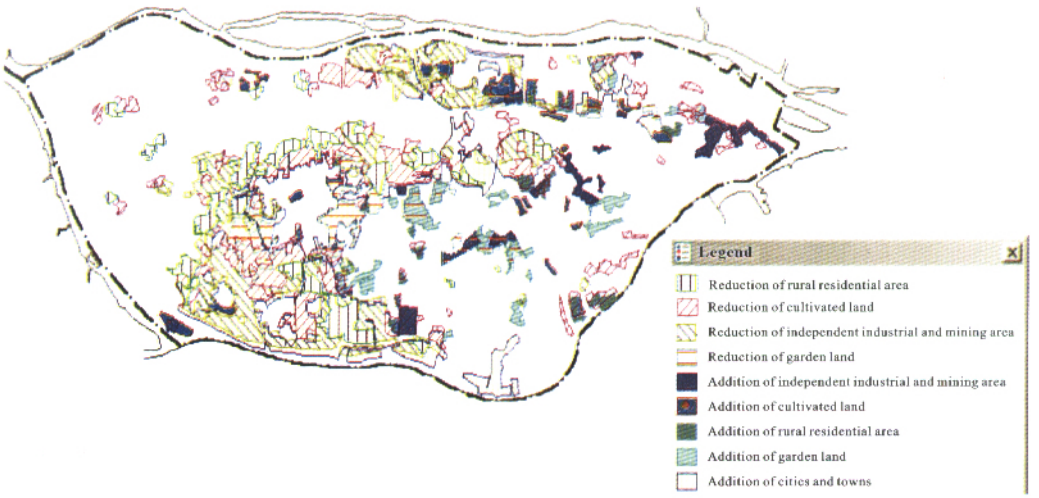

Fig. 4 Change map of some land-use types from 1995 to 1997 in Haizhu District

Table 3 Flowing table of land-use change in 1995 – 1997, 1997 – 1999 in Haizhu District (ha)

Pre-change		Residential, industrial and mining land								Transportation land	
		Cities and towns		Rural residential area		Independent industrial and mining area		Special land			
		1995 – 1997	1997 – 1999	1995 – 1997	1997 – 1999	1995 – 1997	1997 – 1999	1995 – 1997	1997 – 1999	1995 – 1997	1997 – 1999
Cultivated land		6750.04	7513.09	364.85	139.07	3575.79	813.07			611.64	511.59
Garden land		1632.82	1055.86	147.07	252.79	170.75	997.17			417.54	
Woodland			51.36								
Residential, industrial and mining land	Cities and towns										
	Rural residential area	230.12	20.01				78.71			191.43	2.67
	Independent industrial and mining land	1097.88		36.69						184.09	12.67
	Special land										
Transportation land			88.71		1.33		28.01				
Water area		440.89	252.79				86.04	18.01		168.08	16.68
Unused land		910.46	138.07			188.09	2.67				

tion area to total area is 45.60% in 1995, 47.10% in 1997, 48.32% in 1999. Construction land increased 13 801.56ha from 1995 to 1997, 25 089.87ha from 1997 to 1999. The result through overlay analysis basically agrees with practical circumstance and can intuitively depict the spatial patterns and changing trends of the land use.

3.2 Analysis of Land-use Changes Based on Remote Sensing Images

Analysis of land-use changes was conducted in the study area with Landsat-TM satellite images of 1999. The procedure for this analysis is described in Fig. 5. This use of remote sensing imagery provides more de-

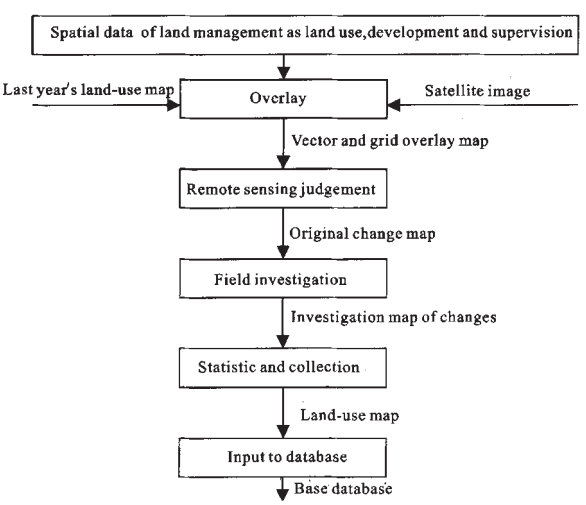

Fig. 5 The route of investigation of land-use changes

tailed information on land use and allows a significant saving in survey time. The time is shortened by 50% – 70% compared with traditional land-use studies. Many changed plots omitted in the past were identified with the imagery.

3.3 Cultivated Land Change

Cultivated land is a basic form of land use in Haizhu District. The major use of the cultivated land in this area is for vegetable growth, which is determined by the geographic location, the administrative district and the development condition of the region. Decreasing in the area of the cultivated land is the general trend of cultivated land, which can be easily illustrated with the statistic data and overlay analysis (Fig. 6).

The reduction of cultivated land is apparently correlated with the increase of population and economic development. It is not difficult to find out that the cultivated land is turned into urban and transportation land. According to the detailed data (House Property Office in Guangzhou City, 1995 – 1999), 94% of the reduction in cultivated land over the years is converted into residential land or industrial and mining land. And the rest is converted into transportation land (Table 4).

Table 4 Land classification after cultivated land change(ha)

	Residential, industrial and mining land	Transportation land	Others
1995 – 1997	6121.06	132.07	0
1997 – 1999	8362.18	511.59	0

Fig. 6 Map of increase and decrease in cultivated land from 1995 to 1997

4 SOME PERSPECTIVE ON URBAN LAND USE

As a main administrative district in Guangzhou City, with the external environment and the continuous increase of infrastructure construction, the process of urbanization of Haizhu District continuously accelerates. The most obvious sign is that urban land is rapid increasing. According to the historical data (Governmental Local Affair Office in Haizhu District, 1992 – 1999), it is shown that the area of urban residential area, industrial and mining land was 367 274.21ha in 1992, but in 1995, it arrived 445 992.89ha, and added 78 718.68ha, which accounted for 21.43% over 1992. In the structure of landuse, urban land changes just confirm this point of view from the overlay analysis map of 1995 and 1997, or 1997 and 1999(Fig. 7 and Fig. 8).

In the districts where land use has been stabilized, the main objective is to adjust land-use structure and enhance land-use efficiency to make best use of the land when land-use development, sustainable development, ecologic and environmental protection are considered. In developing district, based on the principle of "strategic planning, comprehensive developing, systematic construction, infrastructure in first step", the main objective is to carry out comprehensive developing step by step and to achieve planned benefit after construction and planning. In new district, the main object is to improve the protection of land resource, tap the latent power of urban reserved land resource and make a good general planning of urban land use so as to make management a standard and scientific process. As far as the management of land resource is concerned, the limited urban land resource must be properly planned and the urban construction must be carefully coordinated. In order to maintain the cultivated land and

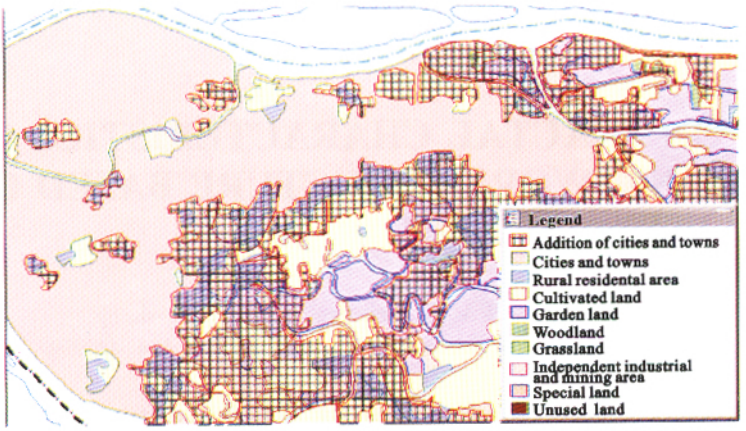

Fig. 7 Change map of cities and towns from 1995 to 1997

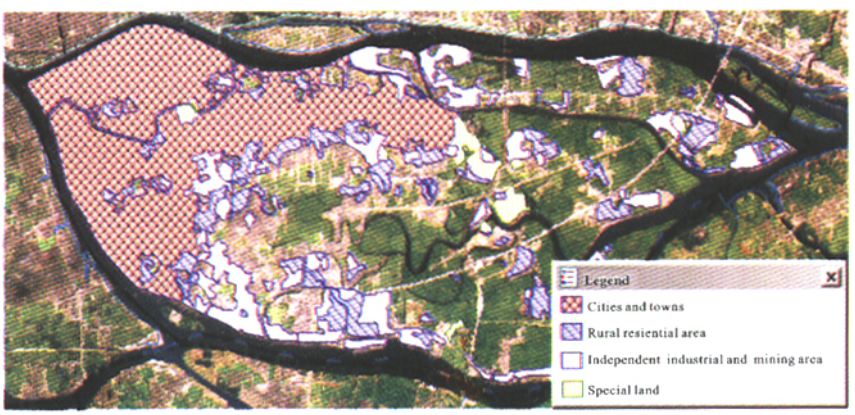

Fig. 8 Overlay between distribution maps of residential area and industrial and mining land in 1999 and 1995

vegetable land, it may be necessary to transform and utilize hilly land and wasteland and develop them into residential or industrial land or parkland.

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