Research on spatial structure changes of urban land use

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Abstract This paper describes a GIS-based spatial analysis method that makes combined use of qualitative and quantitative analysis to characterize land use patterns and predict the trend of future land use changes for the area of Haizhu District of Guangzhou City, China. Spatial techniques are presented to manage land use data and derive information on land use changes. Through the case study for the selected area, it is demonstrated that the method and techniques introduced can be effectively utilized for the analysis of urban land use changes. Based upon this analysis, the paper also provides discussions and recommendations on urban land use planning, urban planning and land management. Two land use maps of the Haizhu District of Guangzhou in 1997 and 1999, together with the remotely sensed images of 2001 are utilized in the current research. It is convenient to spatially reference various statistic data and to combine spatial data with spatial analysis model so as to analyse land use changes in a geographic context, which is especially suitable for the needs of the urban construction, urban management and urban planning departments.

Key words GIS; Guangzhou City; land use; spatial analysis; overlay analysis

INTRODUCTION

Urban construction is continuously spreading and the demand for urban land use is rapidly growing. A lot of agricultural land is being converted into non-agricultural land. When these characteristics are reflected in urban systems, the developing speed of big cities and super cities is quickening (Chen, 1999). Based on the condition of the market, the land resource bears values that are social, economic and ecological. The external expressive form of the interaction of these different values is that the population, economy and land use increases in a given geographic area. Serious problems to be addressed for sustainable urban development include how to properly make use of limited land resources, how to balance actual land use capacities and theoretical capacities, how to scientifically appraise the benefit of urban land use, and how to improve the capacity of urban land use (Chen, 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 spatially reference various statistic data and to combine spatial data to analyse land use changes in a geographic context, which is especially suitable for the need of the urban construction, urban management and urban planning departments. In a GIS environment, various land use data and remotely sensed images can be

effectively manipulated and analysed, which can form a critical basis for land use studies, particularly in deriving dynamic land use patterns and synthesized land use changes (Chen & Peter, 2000).

RESEARCH METHOD

The selection of GIS tools

A commercial GIS system, GeoMedia 4.0 from Intergraph, has been selected to manage spatial data and to provide 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 formats 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, that forms a key ability in the analysis of urban land use.

The selection of study area

The study area in this research is Haizhu District in Guangzhou City, China. The two major reasons for this choice are: (a) Haizhu District is surrounded by the Pearl River, and the 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; (b) Haizhu District represents a transition zone between city and countryside; with continuous urbanization and frequent land use changes in this district. Because of this, 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 90.25 km^2. It is a relatively new region that is developing rapidly.

Database development

The database used for this study consists of two parts that are a basic information database and a special subject information database, respectively. Land use maps are the core of the basic database. The basic database also includes the city's cadastral maps, land use planning maps and large-scale relief maps. The 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 land use on 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

Table 1 Classified system of land use in Haizhu district.

First grade types	Secondary grade types
Cultivated land	Irrigable land, watering land, dry land and vegetable plot
Garden plot	Orchard, other garden plots
Woodland	Forested land, shrubbery, pre-forested land and nursery land
Grassland	Artificial grassland
Residential, industrial and mining area	Cities and towns, rural residential area, independent industrial and mineral land, special land
Transportation land.	Highways, rural road, ports and docks
Water area	River surface, pond surface, ditch, shallows-tidal-flat area
Unused land	Waste land, sand land, bare land, raised path through fields, beach land and others

standard of land use (Yao & 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.

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 the use of GeoMedia 4.0. To achieve the research objective, GIS functions are either used separately or bundled to form sophisticated analytical capabilities. The general procedure is outlined in Fig. 1.

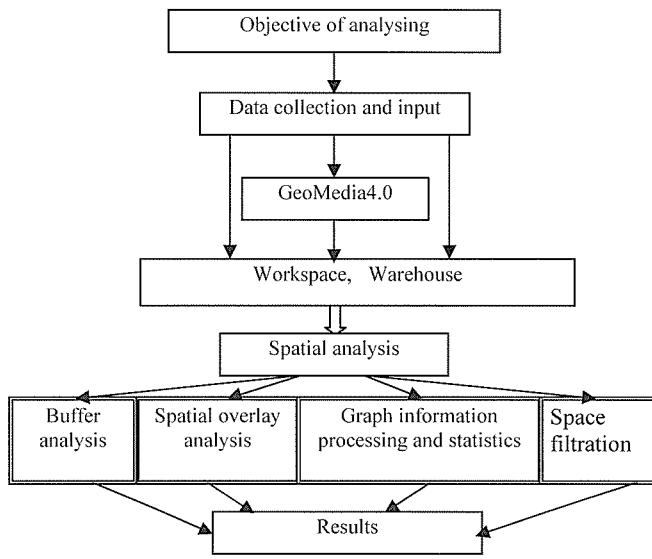

Fig. 1 Flow chart of research methodology.

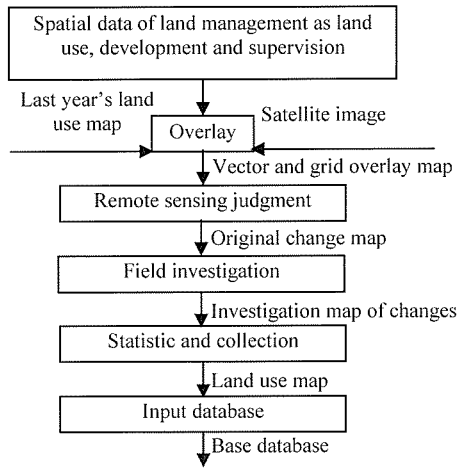

Fig. 2 Flow chart of land use change investigation.

CASE ANALYSIS

In the research, land use maps and satellite images of 1997, 1999 and 2001 are used to derive regional maps of land use changes. The land use data was obtained from the Land Management Department of Guangzhou City. Land use data is obtained from the land use change surveys and provide land use coverage for both the year 1997 and the year 1999. The data for 2001 are satellite images, annotated with data of land use change survey of 2001. Land construction and land development data in the past are also utilized in the research.

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 (Figs 3 and 4). For the Haizhu district the increase in 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 an evident change. Residential area, industrial area, mining area and transportation areas are expanding progressively, while cultivated land and garden land are shrinking over time. When detailed land use changes are analysed, two types of spatial techniques 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 data field 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 analyse this type of change is a comparison of the above-mentioned data

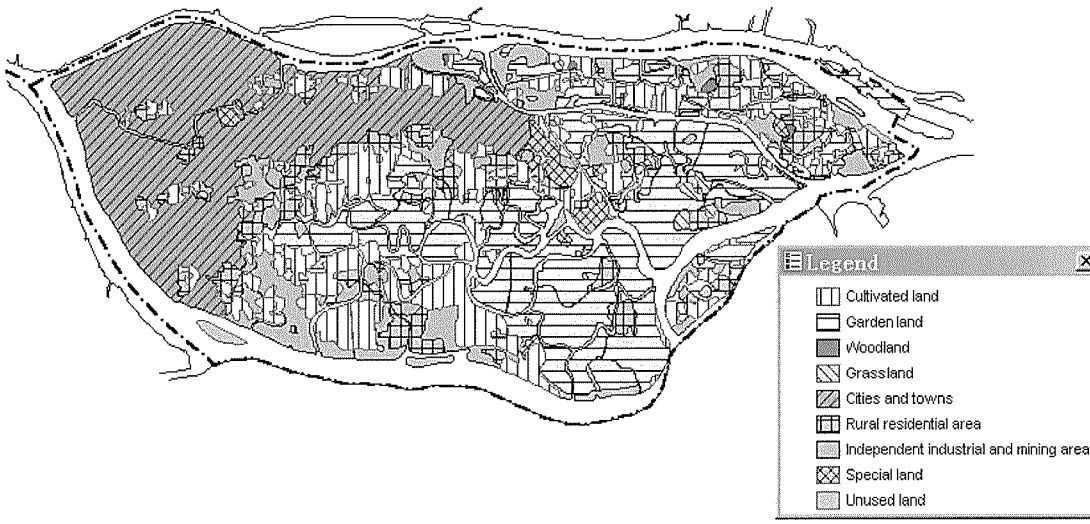

Fig. 3 Land use map (1997) in Haizhu district.

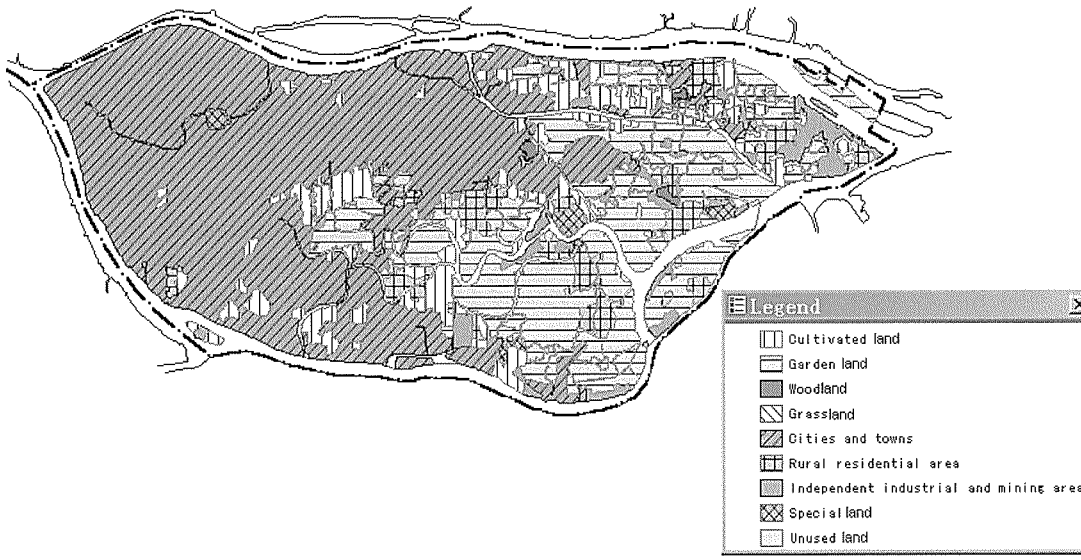

Fig. 4 Land use map (1999) in Haizhu district.

fields in a reverse order. The general change map of land use is obtained 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. 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. For example dry land and irrigated land can be identified as separate categories or merged to form a single category.

It may be argued that the analysis of land use changes should include the analysis of underlying geographic factors that play a role in these changes. In order to understand the effect of each of these factors alone or in combination, the use of stratification treatment and synthetic analysis is necessary. The method to handle little polygons resulting from land use change is to merge them into the adjacent land use types that are the same or close to the type of land use these polygons represent. Usually, a distance index can be derived to measure the compatibility of the land use types between these little polygons and polygons in the neighbourhood (Pan & Zhang, 1999). For example, when the area of a little cultivated land parcel is less than 4–6 mm^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 a layer that represents land use changes and the layer that provides information for identifying these changes to ensure that the updated land use types remain correct.

The area of various land use types can be calculated through the statistic function of graphic basic information of GeoMedia 4.0. The corresponding total area of different land use types is listed in Table 2 .The area of various land use of 2001 in this table is obtained from the analysis of the remotely sensed images. The detailed changes can be identified through overlays of land use maps of different times (Fig. 5 and Table 3).

A major characteristic of land use changes in Haizhu District is that agricultural land is decreasing and constructing land is increasing. The area of agricultural land has been reduced steadily. In 1997 the agricultural land was 305 746.13 ha; in 1999 it was 292 075.63 ha; and in 2001, 280 741.63 ha. The ratio of agricultural land to total land area also becomes less and less, from 33.12% in 1997 to 31.64% in 1999 and 30.42% in 2001. For agricultural land, cultivated land has a greater change, followed by garden land. Construction land has increased steadily. The ratio of construction area to total area was 45.60% in 1997, 47.10% in 1999 and 48.32% in 2001. Construction land

Table 2 Distribution of Land use in 1997, 1999 and 2001.

Land use type	Area in 1997 (ha)	Area in 1999 (ha)	Area in 2001 (ha)
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

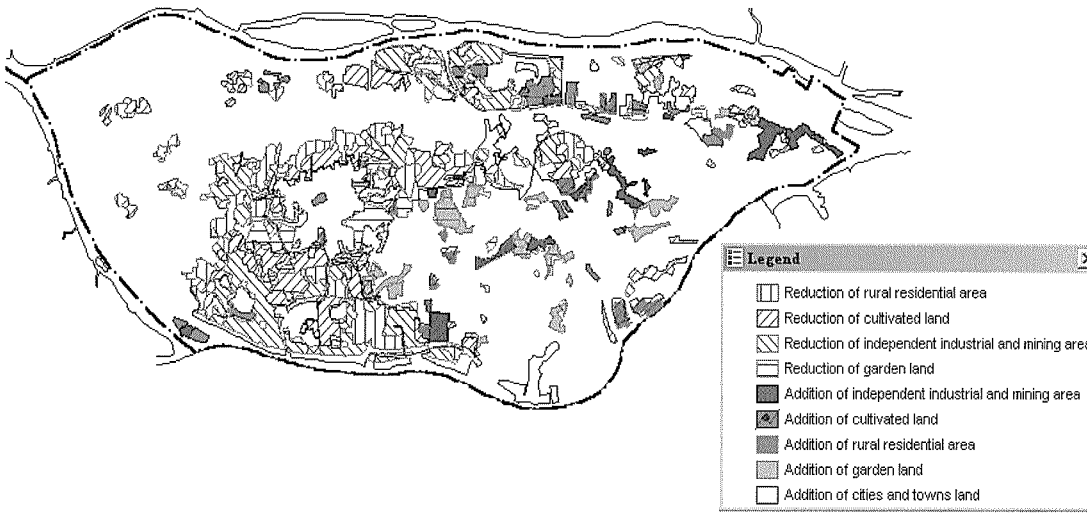

Fig. 5 Change map of part land use from 1997 to 1999 in Haizhu District.

Table 3 Flowing table of land use changing in 1997–1999, 1999–2001 in Haizhu District (ha).

Post-change→		Residential, industrial and mining land								Transportation land	
Pre-change ↓		Cities and towns		Rural residential area		Independent industrial and mining area		Special land			
Change time		1997–1999	1999–2001	1997–1999	1999–2001	1997–1999	1999–2001	1997–1999	1999–2001	1997–1999	1999–2001
Cultivated land		6750.0	7513.1	364.9	139.1	3575.8	813.1			611.6	511.6
Garden land		1632.8	1055.9	147.1	252.8	170.8	997.2			417.5	
Woodland			51.4								
Residential, industrial and mining land	Cities and towns										
	Rural residential area	230.1	20.0				78.7			191.4	2.7
	Independent industrial and mining land	1097.9	36.7							184.1	12.7
	Special land										
Transportation land			88.7		1.3		28.0				
Water area		440.9	252.8				86.0	18.0		168.1	16.7
Unused land		910.5	138.1			188.1	2.7				

increased by 13 801.56 ha from 1997 to 1999 and by 25 089.87 ha from 1999 to 2001. The result through overlay analysis basically agrees with practical circumstance and can intuitively depict the spatial patterns and changing trends of the land use.

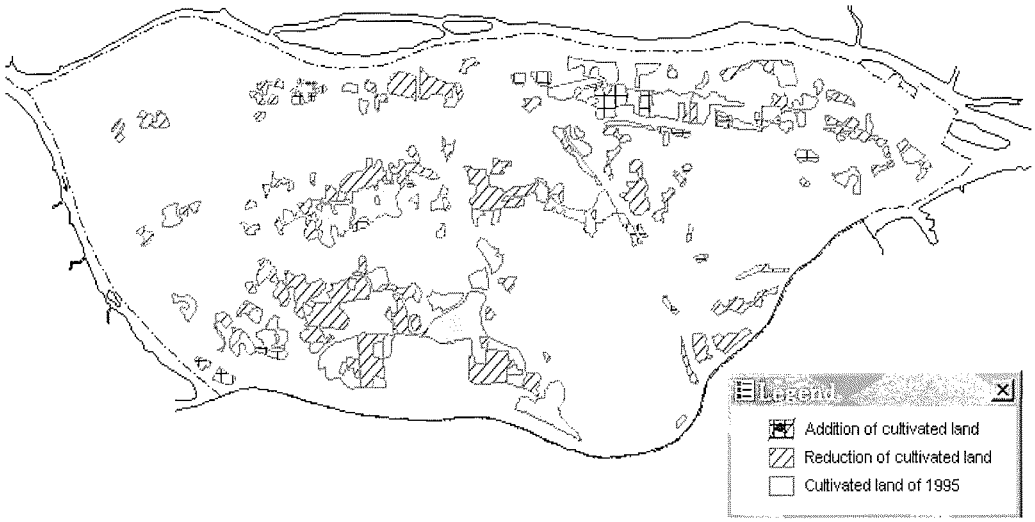

Fig. 6 Increased and decreased map of cultivated land from 1997 to 1999.

Analysis of land use changes based on remotely sensed images

Analysis of land use changes was conducted in the study area with Landsat-TM satellite images of 2001. The procedure for this analysis is described in Fig. 2. The use of remotely sensed imagery provides more detailed information on land use and allows a significant saving in survey time. The time is shortened for 50–70% compared with traditional land use studies. Many changed plots omitted in the past were identified with the imagery.

Change in cultivated land

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. The decreasing trend in the area of the cultivated land 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 when converted will be turned into urban and transportation land. According to the detailed data (House Property Office in Guangzhou City, 1997–2001), 94% of the reduction in cultivated land over the years is converted into residential land or industrial and mining land. The rest is converted into transportation land (Table 4).

Table 4 Land classification after changes in cultivated land.

Post-change	Residential, industrial and mining land	Transportation land	The others
1997–1999	6121.1	132.1	0
1999–2001	8362.2	511.6	0

SOME PERSPECTIVE ON URBAN LANDUSE

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 rapidly increasing. According to the historical data obtained from Governmental Local Affair Office in Haizhu District, the area of urban residential land, industrial and mining land was 367 274 ha in 1992, but it increased to 445 993 ha in 1995, which is equivalent to a 21.43% increase. In the structure of land use, urban land changes just confirm this point of view, see the overlay analysis map of 1997 and 1999, or 1999 and 2001 (Figs 7 and 8).

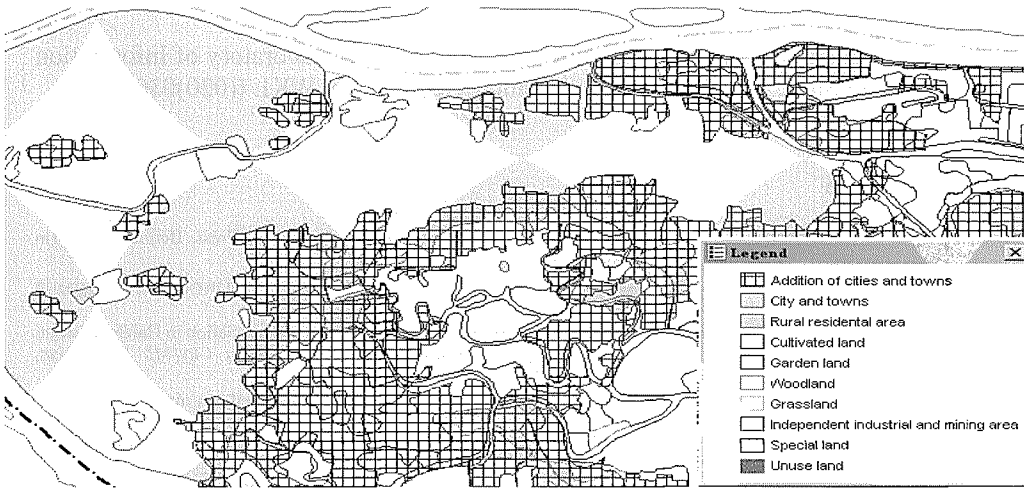

Fig. 7 Changed map of city and town land from 1997 to 1999.

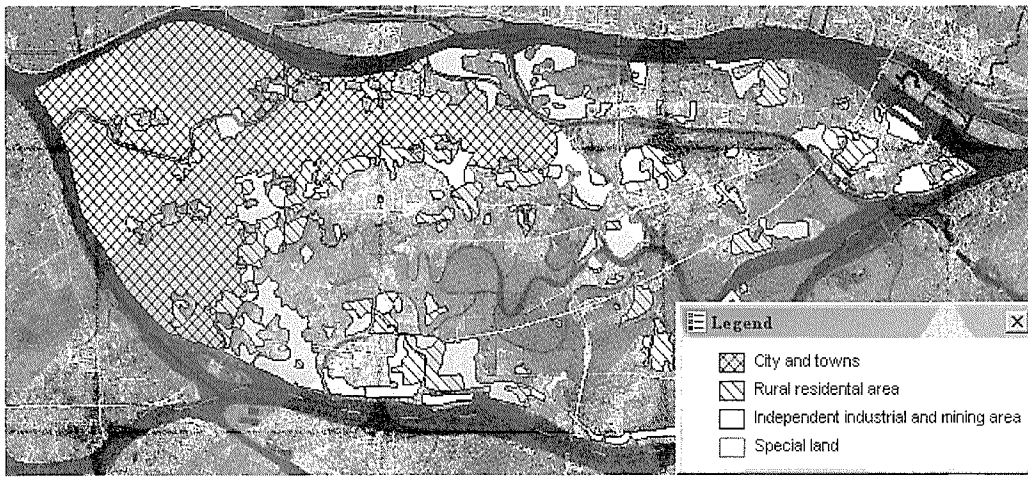

Fig. 8 Overlay between distribution map of residential area in 2001 and industrial and mining land in 1997.

In districts where land use has been stabilized, the main objective is to adjust land use structure and enhance land use efficiency to make the best use of the land when land use development, sustainable development, ecological and environmental protection are considered. In developing districts, the main objective is to carry out comprehensive development step by step and to achieve planned benefit after construction and planning. In new districts, the main objective is to improve the protection of land resource, tap the latent power of urban reserved land resource and make good general planning of urban land use. As far as the management of land resource is concerned, the limited urban land resource must be properly planned and the urban constructions must be carefully coordinated. In order to maintain the cultivated land and vegetable land, it may be necessary to transform and utilize hilly land and wasteland and for residential, industrial land or parkland.

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