Spatial and temporal aspects of land use in the urban-rural fringe in china: a GIS approach

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SPATIAL AND TEMPORAL ASPECTS OF LAND USE IN THE URBAN-RURAL FRINGE IN CHINA: A GIS APPROACH

By

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ABSTRACT

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Submitted in January of 1999, by Zhigang Zhou, Graduate Society, University of Durham, for the Degree of Master of Science.

Since the reform in 1979, China's rural and urban economies have been extremely active. This has accelerated greatly the urbanisation process in the peripheral areas of metropolises. Urban regions extended into rural areas by way of urban sprawl and population concentration in the rural-urban fringe, in which the types and structures of land use changed rapidly. The rural-urban fringe has been an extremely active area in contemporary Chinese socio-economy. It is also a belt of concentration of development and construction of rural and urban kinds. In seeking to apply geographical information systems to such an important area of land use change, this research studies the general principles of the formation, evolution and development of rural-urban fringe with a case study in Tianhe District of Guangzhou Municipality, China.

This research analyses the following three aspects of land use change. Firstly, the land use conditions and situations are discussed in the form of their fundamental characteristics in various years. Secondly, the spatial changes of land uses are characterised in terms of the distance from the city centre including the effects of the physical landscape. Finally, the main emphasis is put upon the impacts of policies on land use distribution. Three different time periods (1973, 1993 and predicted 2010) are applied to compare the changes of land use.

According to the analysis of the trend of land use change in this study, the development of Tianhe District from a traditional rural area to a rural-urban fringe is a considered as result of the Guangzhou urban sprawl. Its specific location, economic development levels, population conditions and policy advantages have influenced this evolution process and brought about the spatial changes and spatial structure of land use.

Keywords: Land use change, rural-urban fringe, China, GIS

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CONTENTS

ABBREVIATIONS

BLAGP: Bureau of Land Administration of Guangzhou Province

BLATD: Bureau of Land Administration at Tianhe District

BPGM: Bureau of Planning in Guangzhou Municipality

BSM: Bureau of Surveying and Mapping

BSMGP: Bureau of Surveying and Mapping of Guangdong Province

BSTD: Bureau of Statistic of the Tianhe District

CAS: Chinese Academy of Science

CCPM: City Council of Guangzhou Municipality

DoE: Department of Environment

ESRI: Environment Systems Research Institute

ETDZ: Guangzhou Economic Technological Development Zones

FAO: Food and Agriculture Organisation

GDFZ: Guangzhou Duty-Free Zone

GDP: Gross Domestic product

GIS: Geographical Information System

GNP: Gross National Product

GVIO: Gross Value of Industry Output

HGS: Headquarters of General Staff

HJZ: Hezhuo Jingji Zuzhi (co-operative economic organisation)

IFTECASC: Institute of Finance and Trade Economics, Chinese Academy of Social Science

IGI: Institute of Geography in Guangzhou

ITE: Institute of Terrestrial Ecology

JJYJ; *Jingji Yanjiu* (Economic Research)

LRA: Land Regulation Act

MoA: Ministry of Agriculture

NADC: National Agriculture Division Commission

NBLA: National Bureau of Land Administration

NCC : National Construction Commission

NCNA: New China (Xinhua) News Analysis

NELUP: NERC/ESRC land use programme

NGPS: Nation Gazetteer Pilot Study.

NIG: :Normal Institute of Guangzhou

NLUC: National Land Use Classification

NPRT: New Pearl River Technique City

PHCE: the Publishing House of Chinese Encyclopaedia

PLA: Peoples' Liberation Army

PRC: People's Republic of China

RCLUCP: Regulation of County Land Use Comprehensive Planning

RCRD: Research Centre of Rural Development

RMB: Ren Ming Bi (Chinese Currency)

RMRB:*Renmin Ribai* (People's Daily)

SERRL: South East Regional Research Laboratory

SLUS: Second Land Utilisation Survey

SRCUIGP: Supplement Regulation of Current Land Use Investigation in Guangdong Province

SSB: State Statistical Bureau

SSLRC: Soil Survey and Land Research Centre

SWB: Summary of World Broadcast

USGS: United States Geological Survey

WLUS: World Land Use Survey

YSCS: Yellow Sea Co-ordinate System

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CHAPTER 1

INTRODUCTION

1.1 Research context

Since the Second World War urbanisation has entered a new development phase in which economic development has produced a strong phase of suburbanisation. In either developed or developing countries, a series of urban expansion phenomena happen extensively in the metropolitan areas which have had a long history and a large scale of urban growth. The transference of population, industries, commercial and housing use of the city to its periphery areas has resulted in interaction and infusion between the rural and the urban. As a result of their mutual insertion, contact and metamorphosis, a particular structure, function and set of landscape characteristics have been formed in the transition belts of the rural and urban regions. Pryor (1968) defined this belt as rural-urban fringe.

The rural-urban fringe is an extremely active area in contemporary socio-economy. It is also a belt of concentration of development and construction of rural and urban kinds. In the fringe, the mutual interaction and contradiction of rural and urban are concentrated and embodied in the following aspects: the invasion by the urban into the rural region; contest and transformation between agricultural land and urban construction land; and re-evaluation of land use mode and efficiency, etc.

Consequently, the land use structures and their evolution over time and space in the rural-urban fringe illustrate the progress of human society, economic and technological development, and different problems and contradictions in the urbanisation process of both rural and urban regions.

Since the reform in 1979, China's rural and urban economies have been extremely active. This has accelerated greatly the urbanisation process in the peripheral areas of metropolises. The urban region extends into the countryside by ways of urban sprawl and population concentration in the rural-urban fringe, in which the structure of land use changes frequently. Unfortunately, study of this type of change has been inactive and largely behind the development of the growing fringe in China. Some reasons for this are as follows.

Firstly, the influence of the traditional policy of 'taking grains as the key link'(Stone, 1982) has had a deep effect on the study of land use. Researchers on land use have usually paid most attention to the study of agricultural land utilisation. Those studies, vary from land resource surveys in the 1950s and 1960s (Shi, 1980), to land resource evaluation and mapping in the 1970s and 1980s (Li, 1985). From the 1990s researchers focused on land productivity and the means of feeding a large population from a finite land area. (Chen, 1992)

Secondly, urban land had not been regarded as a commodity until the 1980s. Urban land use and the transformation of non-urban land into urban land were controlled and allocated by the government. The allocation of land for urban development was determined according to the politics of the day. During this period, geographers concentrated their land use studies on industrial allocation. Since the end

of the 1980s, some researches have been carried out on urban land classification (Hu, 1987; BLA, 1989), urban land valuation (Zhang, 1989) and paid use of urban land (IFTECASC, 1994). All promoted studies on the characteristics of urban land itself.

Thirdly, although there were some studies on land use, they seemed to pay little attention to the studies of land use in the Chinese rural-urban situation. Only in recent years the conflicts between urban land use and non-urban land use in the rural-urban fringe became prominent. These issues gave rise to concern among Chinese scholars (i.e., Cui 1990; Gu and Ding, 1995; Tu, 1990). Generally, these studies are relatively fragmentary and lacking in depth of theoretical discussion. There are, however, systematic studies on the rural-urban fringe, for example, in Shanghai, Beijing and Guangzhou by Gu and Ding (1995); and in Changyang District of Beijing by Chen (1995). These studies are focused on the formation, development and classification of the rural-urban fringe.

Generally, from the standpoint of either theory or practice in contemporary China with rapid urban expansion, it is necessary to discuss the interaction and general principles of land use between rural and urban regions and to study their spatial structure, problems and genesis. In seeking to apply geographical information systems to such an important area of land use change, this research chooses Tianhe District of Guangzhou Municipality as a case study, analysing general patterns of the formation, evolution and development of the rural-urban fringe.

In terms of the selection, Tianhe District of Guangzhou is chosen due to the following advantages:

1) Guangzhou Municipality was an early liberalising city and its economic development level has risen far above other cities and regions in China;

2) Tianhe District is one of the major regions of active rural-urban transition around Guangzhou. Evolving from the traditional rural area of the 1970s to the rural-urban fringe in the 1990s and to a fully urban area in the next decade, Tianhe District is arguably a typical case in the urban expansion of municipalities in China. Studies on such a case area will be useful in discussing the evaluation of land use structure in similar types of regions in China and many other developing countries.

With regard to the research techniques, this research adopts spatial analysis functions of Geographical Information Systems (GIS), carrying out data collection, extraction and analysis so as to provide a quantitative analysis in the rural-urban fringe over time and space, and to be abreast of its changing characteristics. In this research three land use maps (the dates of 1973, 1993 and the planning for 2010) are applied to compare the changes in land use.

This research emphases the development of methodology on how to use GIS to analysis land use change in the rural-urban fringe. If the process of change from the traditional rural area to the rural-urban fringe to urban area can be analysed as a continuation, it will be ideal for the methodology development itself. The analysis of the land use planning is considered on a two fold basis. One aspect is the goal of planning to be realised logically during the planning period; another aspect is to compare planning here with other similar studies in China, and elsewhere in the world, in order to clarify the trends of change in the rural-urban fringe.

1.2 Research objectives

This research, which focuses on how to use GIS to improve the analysis of trends of land use change in rural-urban fringe, is designed:

a) to develop a quantitative case study approach using GIS which might be followed in other rural-urban fringe areas of China and other developing countries for measuring land use change through time and quantifying land-use efficiency in devising economic reform.

b) to seek a GIS approach to obtain empirical evidence on the impact of location measures, economic development, population increase, and land use policy. The approach is centred on two main aspects. In the assessment of land use change, it is necessary to obtain accurate and consistent land use information. It is also advocated that in the studies of impacts of land use policy, it is important to measure the relationship between land use change and other factors.

c) to provide a tool of practical analysis and technique for studies of the rural-urban fringe like Tianhe District. Some theoretical and empirical analyses could be incorporated into this research. It is vital to derive the different sources of data and to build up spatial databases using GIS as a supplementary tool.

d) to analyse the trend of changes in the land use structure of the rural-urban fringe of Tianhe District, using time sequential land use data. It is useful to evaluate the impact of different factors on land use structure based on the performance.

1.3 Scope of the research

The scope of the research can be clarified by summarising the discussions so far. As stressed in the last section (1.2), this study is centred on GIS application for improving procedures for the study of land use change over time and space in the rural-urban fringe. This thesis, then, concentrates on the background, concepts, measurement and analysis of these three aspects in the context of background concepts.

The thesis consists of four parts. Part I provides a review of the empirical and theoretical background to the research, including the research context, objectives and scope; Part II reviews the relevant theory applied in this research; Part III describes the application of the approach designed in Part I to the case study of Tianhe District over time and space. Part IV draws the findings of the thesis together. The structure of the chapters is depicted in Figure 1- 1.

Chapter 2 covers the characteristics of land use and land use change in the rural-urban fringe and GIS approaches to land use analysis; Chapter 3 is centered on the assessment of the influence of land use policy on land use change in China; Chapter 4 describes the general background of the research area. The broad context of Guangzhou municipality and Tianhe District, their location, physical condition and socio-economic development history are discussed.

Chapter 5 covers methodological discussions of how the GIS tool is applied to the analysis of policies and socio-economies, and impacts on the changes of land use

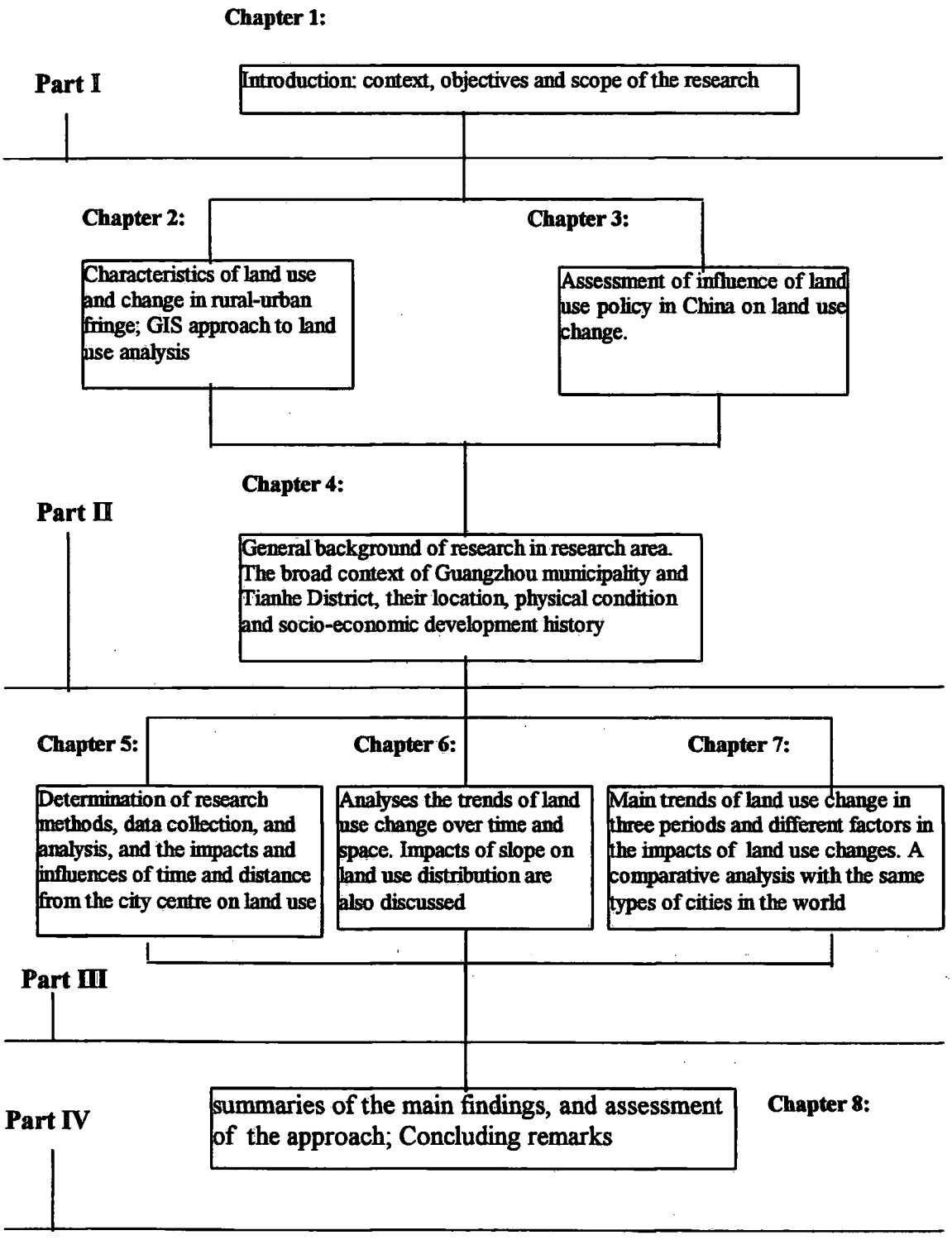


Figure 1-1. The overall structure of the chapters in this research

patterns. This includes the determination of research methods, data collection, and analysis of spatial data, and the impacts and influences of time and distance on land use; Chapter 6 analyses the trends of land use change over time and space. The impacts of slope on land use distribution are also discussed; Chapter 7 summarises the main trends of land use change in the three periods and discusses different factors that have affected land use changes in Tianhe District. Some comparison with the same types of cities in the world is carried out according to the planned land use in 2010, verifying the rationale of the planning of Tianhe District.

Chapter 8 summarises the main findings, and assesses the approach advocated at the beginning of the work in the light of the study undertaken in Tianhe. The strength and weaknesses of the approach are deliberated and suggestions for further research are also presented.

CHAPTER 2

LITERATURE REVIEW

Land use and land use change cover a wide range of research topics. This chapter mainly concentrates on some basic concepts and viewpoints of land use and trends of land use change in rural-urban fringes, and places an emphasis on land investigation and data collection. Afterwards some approaches to land use policy and land use control are briefly discussed, and the GIS approach to land use analysis is also reviewed.

2.1 Land and its use

Land is the fundamental natural resource in economics. However, the term, land, is always debatable. According to Clark (1985, p333), land is the solid surface of the earth where it is not covered by water; it is part of this solid surface distinct from other parts for natural, political, economic, or cultural reasons, and it is part of this solid surface in relation to ownership of rights. The term, land, is regarded as the soil, especially in respect of its quality. Sometimes it means the countryside, particularly farmland, as opposed to the city (Robert and Peters, 1981). Generally, the use of land has been of major importance to human beings. Mather (1986, p1) writes:

"Over the span of human history, the human being has drawn most of **his** **sustenance** ***and much of his fuel, clothing and shelter from the land. Land has been the human's habitat and living space; land has been a matter of life and death, of survival or starvation."***

2.1.1 A brief history of land use research

Quite a large number of disciplines pay attention to the study of land use. They concern themselves not only the principle of the land use, which largely involves economics and ecology, but also with the result of human decisions operating within social, political and legal frameworks.

The concept of land use encompasses a variety of the basic elements of human geography. At first glance the term may seem self-explanatory in this context. A general definition of the subject can be given in the way in which Best (1980) noted: ***"Land use deals essentially with the spatial aspects of all man's activities on land and the way in which the land surface is adapted, or could be adapted, to serve human needs."*** (Best, 1981, p20)

An analysis of land use patterns in a particular area reveals a great deal about the way the inhabitants of the area live. The information on the land use pattern can be drawn from economists, agricultural experts, urban planners, geographers, and others in different ways.

The geographic analysis of land use goes back to the pioneering work of J. H. von Thunen (1966). In an attempt to explain rural land use in southern Germany, von Thunen invented and developed a simple land use model.

In the early part of the twentieth century American geographers began to become interested in land use concepts. In their classic article on fieldwork, W. D. Jones and C. O. Sauer (1915) emphasized land use concepts. Started in 1922, the Michigan Land Economic Survey was the first government-sponsored land use project (C. P. Barnes, 1929). During this same period, an increasing number of geographers became concerned with land use mapping techniques (V. C. Finch, 1933 and G. D. Hudson, 1936). Perhaps the most ambitious early study of land use, however, was Derwent Whittlesey's(1936) well-known classification and mapping of agricultural land use over the entire world.

Since von Thunen (1966) and Whittlesey (1936), land use in rural areas has been a topic of interest to geographers. A number of authors have updated and developed Von Thunen's work, but Michael Chisholm (1967) has done the more conceptual research on rural land uses. At the same time, from a theoretical viewpoint, David Harvey's (1966) analysis of agricultural land use patterns was a useful intuitive development. Case studies of land use in particular rural areas concern geographers; for example, John F. Hart (1980) illustrated land use problems in Carroll County, Georgia and M. L. Shelton (1981) examined the relationship between land use and runoff in a rural area.

Although much of the early focus of geographers was placed on rural or agricultural land use, several significant studies explained urban land use patterns. Those studies involved a variety of land use patterns. For example, the concentric zone model, developed by E. W. Burgess (1925), comprises several concentric zones of land use undetermined width surrounding a central city. Homer Hoyt's (1939)

sector model proposed that cities were organized according to concentric zones and radial sectors; that is, specific kinds of land use tend to spread outward from the central business district along axes of transportation. The multiple-nuclei model of urban land use, developed by C. D. Harris and E. L. Ullman (1945), stated that cities do not have a single nucleus that determines land use patterns, but a number of separate nuclei, each influencing land use pattern in urban areas.

With respect to the urban areas there also existed different kinds of viewpoints on the importance of the land use concepts. Larry S. Bourne (1976) pointed that, urban land use "is one of the key elements in theories of urban spatial organization and it is a physical manifestation of the social and economic stratification of industrial society." To Bourne, "land use control, despite criticism, remains the most important instrument available to local government to influence the location, design, and functional character of urban growth, and thus indirectly to affect the general well-being of their constituents" (1976, 533).

Analysis of land use issues has prompted many geographers to become concerned with land use policy decisions and land planning techniques. Further discussions of these areas can be seen in literature in which, for example, and Lee Guemsey (1973) have evaluated land use policy decisions, and T. William Patterson (1979) explained land use planning techniques.

2.1.2 The structure of land use

The study of the structure or composition of land use is important. The structure of land use varies greatly from nation to nation, and it is rather fruitless to

search for any generalizations or norms at the global level. However, extensive similarities emerge between countries in different settings, and some of these variables, such as the nature of the environment, population density, history and government policy are very influential.

Generally in the analysis of the structure of land use, some major units of data variables can be used to delimit arable and permanent cropland, permanent pasture, forest and woodland, and other land. Using Food and Agriculture Organization (FAO) classes, some instances of the structure of land use can be demonstrated in Table 2-1. These data clearly show the patterns of land use at the national and global level.

Table 2-1. Some instances of the structures of land use at the national level

	Arable and permanent cropland	Permanent Pasture	Forest and woodland	Other land
	(percentages of the total land area)			
World	10.8	23.9	32.2	33.1
USA	20.9	26.7	32.0	20.4
Former USSR	10.5	16.8	41.3	31.4
UK	29.9	8.8	7.8	13.5
EU	36.2	28.0	21.6	14.2
Australia	5.4	59.4	18.1	17.1
Brazil	6.4	17.0	70.2	6.4
India	55.4	4.4	21.8	18.3
Japan	14.7	0.8	67.5	16.9
Nigeria	32.8	21.7	19.3	26.2

Source: A.S. Mather (1986), pp.104

It is necessary to note that the structure and pattern of land use also show enormous variations within individual countries. Mather(1986) argued that many of these variations are based fundamentally on environmental contrasts between mountain and lowland or humid and arid areas. Remarkably, it follows, therefore, that even if individual countries have similar overall land-use structures, the actual

patterns of land use within them may vary, and different problems and trends will be experienced within the different regions, or even local areas.

2.2 The evolution of the rural-urban fringe

Over the 20th century, urbanization, as a result of industrialization, has entered upon a new trajectory of suburbanisation. In the metropolitan areas, either in developed countries or in developing countries, the expansion of suburbanisation from the city centre to the peripheral area takes place on a grand scale, which leads to the immigration of population, industries, and housing etc. Form the city centre outward to the peripheral areas and the broad countryside. At the same time, the interaction and mutual effects between urban and rural regions are gradually enforced. From the viewpoint of the territorial structure and function, a kind of new intermediate territorial belt is emerged, in which the rural-urban fringe is formed, different production factors are concentrated and the land use structure over time and space changed.

2.2.1 The concept of the rural-urban fringe

Through an extensive range of literature review, many definitions of the rural-urban fringe have been found which provide variations on its attributes, scope and function. Most knowledge and understanding of it are even ambiguous. Therefore, it is necessary to explain briefly the origin of the concept and changes, then give a clear definition of the rural-urban fringe.

Andrews (1942) pointed out the new concept of the rural-urban fringe when he studied the land use types of urban and peripheral belts. In the 1950s, McKain and Burnight (1953) argued that the transition of urban and rural should be divided into two parts of 'limited fringe' and 'extended fringe' in which the former is similar to the urban peripheral region and the latter is located farther from the urban centre. In the 1960s, Conzen (1960) focused on the studies of urban landscapes and thought that the urban fringe was the front area of the territorial expansion of urban areas and it could be divided into three compositions of internal belt, intermediate belt and outer belts. Up to the 1970s, Carter and Wheatley (1979) argued that the traditional studies on the urban fringe were not suitable for understanding their changing functions and they pointed out the multifaceted approaches to the transition of the fringe belts, emphasizing on the demographic and sociological characteristics. In the 1980s, Desai and Gupta(1989) pointed out the concept of rural fringe in which the comprehensive index (suburbanisation index) was used to divide the two fringes of urban and rural.

So far, we may summarize that the rural-urban fringe, as pointed out by R. G. Pryor (1968), is a transitional belt of land use, social and demographic characteristics, and is located between the continuous built-up region in the central city and agricultural hinterland outside the city nearly without urban residents and non-agricultural land uses.

Over recent years, as urban expansion has accelerated, the rural-urban fringe has been attractive to many Chinese researchers. A large number of studies about the definition, and spatial structure of the rural-urban fringe have been carried out (Han and Yi, 1987; Gu, 1988; Gu and Xiong, 1989; Yan and Li, 1989; Huang and Chui,

1990; Wu and Mao, 1990; Tu, 1990; Gu and Chen, 1993; and Chen, 1995). Chen (1995, p3) argued that the rural-urban fringe is a distinctive transitional region recently formed from the interaction, infiltration and merging of factors and functions between urban and rural areas.

Generally, the rural urban fringe is a region where the problems of land use are various and most intense.

2.2.2 Land use in the rural-urban fringe

It is quite interesting that most studies about the rural-urban fringe in the West are based on the analysis of the land use in urban fringe. It is undoubtedly inevitable that while urban areas grow and evolve, naturally many other land use changes take place. In the general context and from time to time, the growth of urban land use and the rate at which it is being converted from agricultural uses gives rise to concern. What has changed, for example, in Europe, is the focus of its concern. There are few worries over maintaining food supply now than that in the era of European Community food surplus, instead, urban land use changes have been placed on more broadly based concerns about limiting urban growth in order to maintain environmental and social qualities of life.

Although there is more land and there have never been significant food shortages in the United States, even so concern is now being expressed. According to the research of Volkman (1987), between 1967 and 1975 there was a huge accelerating loss of farmland, resulting in 354, 000 ha of actual or potential cropland being concerted to non-agricultural uses.

Also in Europe the 1960s witnessed widespread demographic and economic growth, resulting in urban expansion. However, by 1970, with widespread economic recession and decreasing population growth, the rate of land conversion slowed markedly in most countries. Even in the improving economic climate of the 1980s it appears to have remained relatively low. A similar tendency, albeit from a higher level, can be observed in Japan where the National Land Agency estimates that the areas converted from forestry and agriculture to urban use rapidly.

Another source of information related to land use change in England and Wales has been provided by the statistics collected annually since 1985 in a trial project run by the Department of Environment (DoE 1986; 1987; 1988). The statistics are compiled from information gathered by Ordnance Survey field staff in the course of routine map revisions. The exercise is undertaken each year and it does provide the only available national indication of the dynamic processes of land use change.

The interesting conclusion is that in Britain, most other European countries and Japan, the rate at which land was being converted to urban uses slowed markedly during the 1970s and 1980s, but that in North America it continued to increase. To a much greater degree, this character reflects different planning regimes, different national realities concerning land availability, and differential performances of the national economies. All of these in turn were manifested in the tendency for house building rates to fall during the period in Europe, whereas they increased in North America (United Nations 1989).

More recently, Firman (1997) examined the impacts of economic development on land conversion in the Northern Region of West Java and discussed their

implications for urban and regional development. Mori (1998) carried out a comparative research for land use conversion between Japan, Britain and the Netherlands

Studies on land use in the rural-urban fringe in China have been attracted great attention since 1990s. Gu and Ding (1995) conducted a systematic analysis on the fringes of China's municipalities, and studied their characteristics based on the four aspects of population, society, economy and land use. Their analysis on the case of rural-urban fringes in Shanghai, Beijing and Guangzhou indicated that the major characteristics of China's rural-urban fringes include highly utilized agricultural land and moderate utilised urban land, interactive land use, and the sparsity of agricultural land use and continuity of urban land use. Chen (1995) made a thorough inquiry into the interaction and development of different patterns of land use between urban and rural areas in Beijing. By using hierarchical clustering methods, the rural-urban fringe in Beijing was divided into urban expanded area, garden and agricultural area, highly cultivated agricultural area and diversified agricultural area.

2.3 Land investigation and data collection

2.3.1 Land classification

For the study of land use changes, some detailed observations need to be arranged into groups, using some classification methods. It is undoubtedly surprising that there exist many kinds of land use classifications. As pointed out by Anderson et al. (1976, pp.4), each classification is made to suit the needs of the user, and few users

will be satisfied with an inventory that does not meet most of their need. As the needs of users may vary, there are many classification systems

In practical study and work, much land use survey leads not to classification in a statistical sense but to a discriminate analysis - as argued by Rhind and Hudson (1980, p34), "rather than grouping the geographical individuals on the basis of similarity to provide groups of like individuals for which names are then sought, each individual is compared with an a priori scheme; the individuals are then slotted into pigeon holes one at a time".

The number of classes used is an interesting characteristics of classifications. Usually, it can be found that little difficulty is seen in allocating geographical individuals to classes with small or very large numbers of different classes of land use, though much information is obviously lost in the first circumstance.

The most famous classification of land use in the world so far are the World Land Use Survey (WLUS) and the Second Land Utilization Survey (SLUS). Both of these classifications derive largely from the work of Sir L. Dudley Stamp and others such as E. C. Willatts in the early 1930s (Stamp 1931; Stamp and Willatts 1934). The WLUS classification, which was adopted in 1949 and orientated towards agricultural interests, was always intended to be further sub-divided in local circumstances; A comparison between first order categories in the World Land Use Survey and Second Land Utilization Survey classifications is shown in the Table 2-2.

The WLUS classification in its basic form was designed in order to suit the production of maps at circa 1/1 million scale, and to be sub-divided for more detailed work (Kostrowichi 1970). The great majority of the mapping for the SLUS, begun in

1960 and completed some ten years later, was carried out at 1/10560 scale and published at 1/25000 scale. In regard to the planners and administrations with a direct interest in settlement and industry, the sub-divisions of WLUS series and Second SLUS classes are of particular interest. On the whole, it is clear that much of the classification is orientated towards rural areas. In addition, there also exist other well-known classifications from certain institutions, fsuch as the United States Geological Survey (USGS), the DoE Developed Areas, the National Land Use Classification (NLUC) and the Nation Gazetteer Pilot Study (NGPS).

Table 2-2. Comparisons between first order categories in ULUS and SLUS classifications

WLUS	SLUS
1 Settlement and associated non-agricultural lands	1 Settlement (residential and commercial)
2 Horticulture	2 Industry
3 Tree and other perennial crops	3 Transport
4 Cropland	4 Derelict land
5 Improved permanent pasture	5 Open spaces
6 Unimproved grazing land	6 Grass land
7 Woodlands	7 Arable
8 Swamps and marshes	8 Market gardening
9 Unproductive land	9 Orchards
	10 Woodland
	11 Heath and rough land
	12 Water and Marsh
	13 Unvegetated land

Sources: After: David Rhind and Ray Hudson, 1980 p35

2.3.2 Land use survey and mapping

This section review some of the methods used in the collection of land use data. Still, the emphasis is placed on surveying and mapping, both from a geometric and from a land information point of view. There are a series of techniques to be

considered: field surveying, photogrammetry, and remote sensing. Each contains a set of tools that differ in measurement, principle and practice. Each of them, however, may be regarded as complementary, the circumstance dictating whether one or the other or the combination is appropriate. All three sets of techniques are concerned with the discovery, recording, and presentation of spatially referenced data.

The field survey can use the techniques of geometrical measurement, classified as graphical or numerical, though some are in practice a combination of both. Numerical data can always be drawn on a map in graphical form and can be recorded and stored at one to one scales with the environment. Graphical data are restricted in accuracy to the scale of the map on which they were compiled. Using the process known as digitizing, they can be converted to numerical form so as to be held in a computer with high levels of precision. Briefly speaking, some ordinary procedures can be adopted as follows: plane tabling, chain survey, angular, distance measurement and traversing.

Photogrammetry is a collection of techniques for recording and measuring what is already on the ground by taking measurements on photographs. These techniques are only cost effective when economies of scale can be applied. They are relevant to topographic mapping and to the initial compilation of a land register, but rarely to its daily maintenance. The first essential step is to obtain an aerial photograph, then the height measurements can be carried out. In due course, the techniques of air survey and ground survey should be used as complementary methods, and the ideal is often the combination of both of them. Finally, the

photographs should be stored as a data of land use records. The details of how those may be done can be referenced in traditional textbooks on photogrammetry.

Remote sensing is made of a set of techniques that extend the range of human perception beyond the visible spectrum. Such an identity is derived from the science of analyzing objects, from the radiation they emit or reflect, each object having a characteristic 'fingerprint' or spectral signature'. Certain objects, which are viewed by radiation, become distinctive and detectable while the human eye cannot see them. The images viewed from satellites give a more holistic view of the earth even within the visible spectrum; most people appreciate the application of remote sensing mainly because of the impressive way in which the earth appears when photographed from space. Remote sensing has been closely associated with satellite technology and images from space. Most remote sensing is based upon electromagnetic radiation at frequencies that extend from gamma rays. The pictures that result from remote sensing may represent near-instantaneous views as in conventional photography.

In summary, there are two components in the survey and mapping of detailed information, that is, the classification and coding of the features, and the determination of their position. Photogrammetric methods are often preferable if the data are of the type that can be brought up to date periodically, as with small-scale maps, or if mass production methods are needed, as in the initial compilation of a land register. In the management of the database, a major problem lies in reconciling data from different standards of accuracy and precision. This can be solved by associating with each value an attribute indicating its reliability or origin. The differences are insignificant for the purposes of graphical display.

2.4 Distance decay theory

It is necessary that some theoretical models be discussed in studying land use changes. Generally speaking, many models of urban land use have been developed by economists and geographers, and a large proportion of them can be described as bid-rent models. These are based on an assumption that land using activities have different needs to locate close to the centre of the city and will bid for land accordingly. Consequently, this leads to a gradient of intercities of land uses and land price which declines outwards from the centre in a more or less predictable manner. All activities are so optimally located that utility, or profit, is maximized. The provenance of most these models can be derived from the work on agricultural land published by Von Thunen in 1826, but it is generally considered that Hurd (1903) first applied it to urban areas. There is a large number of works to be given credit for the further development of these models, for instance, Isard (1956), Alonso (1964), Muth (1969), Mills (1972) and Miyao (1981). Some summaries are well evident in those works of Balchin and Kieve (1977), Hallett (1978), Hudson and Rhind (1980), and Fujita (1989).

In fact, the bid-rent formulation is based upon the assumption that different activities will have bid-rent curves which vary in form according to their need to be at the centre of the city. This, in turn, depends upon the nature of the activities, their ability to take advantage of highly priced central sites and their sensitivity to transport costs. This theory provides the rationale for the arrangement of land uses and values indicated in Figure 2-1.

For all activities there will be a trade-off between the high costs of central area land and the high cost of transport incurred by locating further out, but the effects of this may be more apparent for residential uses, or for individual households within the residential sector, for whom the utility of a central location is lower.

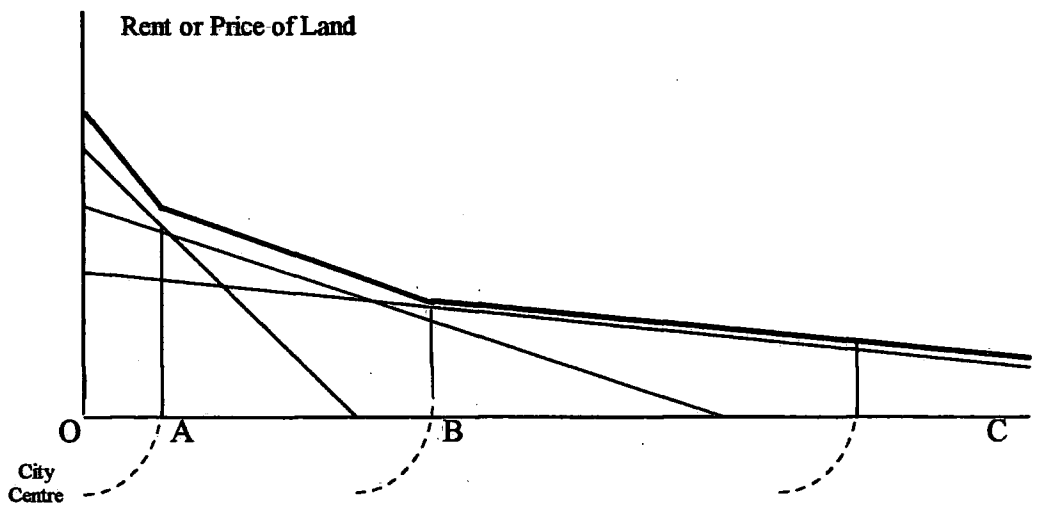


Figure 2-1. Urban land use and the bid-rent model

Sources: after Philip Kivell, 1993, pp.19

This bid-rent model provides an explanation of urban structure and land use changes. The key concepts, i.e. land values and accessibility to the urban centre, have been applied in a variety of circumstances to the more specialized study of urban retailing, especially with respect to the structure of the urban core. Some further consideration about the transport cost, capital and land ownership can be found in the traditional literature on location theory.

2.5 Land use policy and land use control

Land use policy involves a broad range of activities. Many authors argued the nature and dimensions of land use policy (Andrees, 1972; Ratcliffe, 1976; De Neafville, 1981, Mather, 1995, Kivill, 1993). Using this policy, governments seek to influence the use, planning, ownership, price and benefit of land, not least within the process of development.

Generally speaking, the purpose of land use policy is to control development (Kivell, 1993), either in the sense of shaping land use patterns, or in the wider sense of ensuring a degree of fairness and redistribution of gains to be made. But in the traditional context, its emphasis has been placed upon guiding or restricting new development. This has led to considerable pressure on new policy in the areas of rapid urban growth. Therefore, land use policy evolves as a response to problems derived from the processes of development and it may originate from narrow land use concerns, or from broader fiscal, social or ideological considerations.

Such land use policy can be defined as the framework, which relates land ownership, land value, land use planning and development policies, but at an operational level and practical process, there are many variations. As Barrett and Healey (1985) pointed out, the land policy should be seen not simply as a set integral part of broader economic and social policies, although of course these in turn may be imprecisely specified. For this reason it is important that land use policy should not be determined solely by economists, administrators, surveyors and other land professionals, but that it should also have a contribution from geographers.

Another related distinction exists between equity and efficiency in the derivation of land use policy, but an equally important distinction may be made between aspects of control and promotion of development. Control is aimed at the regulation and limitation of the free market and some of the powerful agents within it. Promotion involves the encouragement of desirable forms of development. In the early 1980s, however, a slump in development of almost all kinds caused the pendulum of land use policy to swing towards the promotion of development, especially as a means of facilitating economic growth (Kivell, 1993).

Kivell (1993) summarized the ways of land use control as aspects, that is, externalizes, urban sprawl and price, profits and gains. Land use policy needs to be able to regulate externalities, which lead to a loss of welfare by the general public, or by individual third parties, caused by development where only the private costs and benefits have been accounted. Land use policy puts urban sprawl into the mainstream of geographical analysis.

The measures of land use policy are something assumed to be mainly concerned with controlling undesirable aspects of the free market, but a balanced view requires that they should also be addressed to the positive promotion of desirable development. Some measures can be adopted through the following means, for example, development and redevelopment, good town planning, public goods, and redistribution and welfare (Kivell, 1993).

As regards the instruments of land use policy, the control is carried out by means of land use planning and zoning, taxation and other fiscal measures(Andrees, 1972; Ratcliffe,1976; Mather, 1995). The importance of land use planning or zoning

involves the state, usually in the form of local authorities, laying down generalized structure plans, or more detailed local plans indicating where development will be permitted and in what form. In addition, fiscal measures may be used in a great variety of ways to guide and regulate the land market and the development process. The main aim is to raise revenue, with any effect upon land development being merely a corollary, but a few fiscal measures are employed specifically to influence land use or development.

Governments mainly use policy to promote the development of land, especially if market forces are not achieving the desired results. The past three decades, which have witnessed the stagnation and restructuring of many urban land markets, have also seen the operation of a plethora of policies designed to promote development (Kevill, 1993). There are three common aspects on which measures can be taken in the process of promotion. First, government acts as developer. Government involvement in development can take place at many levels up to and including the use of government bodies to act directly as developers. In the majority of these cases the state, normally in the form of local government, takes on all of the developer's roles, including land acquisition, finance, design, planning, construction, ownership and management of the completed scheme. Second, government can effectively support for markets. Most governments accept that a completely unregulated free market does not produce the most acceptable overall environment for urban development, and that some degree of intervention is necessary. Third, some grants and other promotional legislation can be adopted. Where the local urban economy has collapsed, and the development potential has fallen, perhaps to nil, as in

some British and North American inner city areas, large incentives may be necessary to stimulate the market (Kivell, 1993).

2.6 GIS approach on land use analysis

2.6.1 The role of GIS on land use analysis

There are many definitions of the Geographic Information system (GIS). Maguire (1991, pp11-19) had a good summary for the discussion to the definition of GIS. As an integrated spatial data handling tool, GIS can be defined as a system used for (1) input, (2) storage, (3) manipulation and display of geographic data (Ripple, 1985).

Much of the current discussion on geographical information systems (GIS) can be seen in two streams. One stream is about the technical aspects: design, specification, hardware and software requirements, methods for data input, and data storage structures (for example, see Openshaw et al. 1987; Rhind, 1988; Mason et al. 1994; Burrough and Frank, 1995; Mainguenaud, 1995). Another stream is on applications of GIS methods, or possible roles for GIS methodologies in science and society (for example, see Aspinall, 1993; Jankowski, 1995; Carver et al. 1995; Stein et al. 1995; Radke, 1995).

An area in which GIS technology and associated methodologies have the potential to make an important impact is land use management and planning, and specifically in investigating the possible effects of implementation of policy (Worrall, 1989). In such applications, a modeling approach to land use is necessarily included, models allowing interpretation of the likely effects of policy measures by attempting

to predict the extent to which the policies concerned have solved the problems they are intended to address. Aspinall (1993) presented a framework for applying GIS based methods to a wide range of land management and land use planning issues including the interpretation and formulation of land use policy. The framework allocates a central role to GIS in integrating policy with land resources and land use, thereby providing a powerful tool for land managers, planners, and policy makers. Noteworthy examples of using GIS in land use studies include the NERC/ESRC land use programme (NELUP) at the Institute of Terrestrial Ecology (ITE) (Whitby, 1992), the development of environmental information systems for planning sustainable land use at the Soil Survey and Land Research Centre (SSLRC) (Hallett et al., 1996), and the programme of land use statistics at the South East Regional Research Laboratory (SERRL) (Bibby and Coppin, 1994).

Meanwhile, scientists have also researched the extension of GIS capabilities through the integration of models within a GIS for land use assessment and land use planning (Quarmby et al. 1988). The most commonly used models which can be integrated with GIS are rule-based and knowledge-based models. In rule-based models, rules are used to weight datasets in the geographic database. Quarmby et al. (1988) used rule-based weighting of data in land use planning, allowing land to be zoned according to the relative importance of different data. In knowledge-based models, equations and relationships developed outside the GIS are applied to datasets in the geographic database (Sivertun et al., 1988). An application is the prediction of the location and effect of future afforestation in the Grampian region, Scotland (Aspinall, 1993). This application produces a map of the likely distribution of future

afforestation, which can be summarized using overlay techniques against a variety of spatial units. Such models certainly have constraints and new models are being developed (e.g. Geetman and Van Eck, 1995), however the potential does exist whereby plans and policies can be formulated on the basis of a wide evaluation of their likely consequences.

In this study, the use of GIS is intended to contribute to an application in land use change over time and space following the advice of Chorley:

'GIS as a tool is about aiding managers to carry out their jobs more efficiently and effectively, and, more particularly, about better decision-making'. (Chorley, 1988, p3)

2.6.2 Spatial database development for land use analysis

A database is a collection of data that can be shared by different users. It is a group of records and files that are organized so that there is little or no redundancy.

Database development is fundamental to spatial analysis of land use. A large literature examines the operations involved in land use database development. There are quite a number of advantages of a database. Palmer (1984) concluded that the advantages of a database management system include: flexibility, for the system permits existing data to be used for purposes that were not envisaged when it was collected; simplicity, in that the data base gives those with permitted access a global view of the data within an enterprise; fewer restrictions on what users can do with the data, compared to fixed file structures; centralized data control, which ensures that all users operate on the same data and that they have an identical meaning to all users;

easier implementation of new applications; easier program writing; data independence and standardization.

The procedure of database development can be loosely divided into two stages: data input and data manipulation.

2.6.2.1 Data input

Data input is the operation of encoding the data and writing them to the database. It is the most important and complex task to create a clean, digital database, upon which the application of the GIS depends. According to Burrough (1986 p57-80), two aspects of the data need to be considered separately for GIS; these are first the positional or geographical data necessary to define where the graphic or cartographic features occur, and second, the associated attributes that record what the cartographic features represent. In terms of the spatial and non-spatial attributes, the ability to process the cartographic features is the main distinguishing criterion between automated cartography and geographical information processing. There are three headings under which data input to a GIS can be best described, that is, entering the spatial data (digitizing); entering the non-spatial, associated attributes; and linking the spatial to the non-spatial data. At each stage, there should be necessary and proper data verification and checking procedures to ensure that the resultant database is as free as possible from error.

Digital mapping is the process of producing maps from spatial data held in numerical rather than in geographical form. Although the concepts of digital mapping are inherently simple, the practice tends to be more complex (Dale and McLaughlin

1988). In practice, digital mapping is made up of three operations: data capture or data acquisition, which aims to convert data into digital form; data processing, in which the data can be transformed into various structures to serve different functions; data presentation, using either computer graphic techniques for visual display or electronic methods for transmitting the data to other users.

The digital mapping involves a series of activities. According to Dale and McLaughlin(1988), these activities in detail are shown in Table 2-3.

Table 2-3. Brief outline of different activities in digital mapping

Activities	Examples
1. Data acquisition	Line digitizing
2. Data classification	Allocating feature codes
3. Data structuring	Vector, raster, and topological
4. Data restructuring	Raster to vector conversions
5. Data editing	Corrections, squaring buildings
6. Data transformations	Map projects
7. Data selection	Feature overlays
8. Data generalization	Small-scale map compilation
9. Data enhancement	Graphic displays, symbolization
10. Data analysis	Calculating areas

Source: after Dale and McLaughlin (1988), pp.127

2.6.2.2 Manipulating land use data

Errors can arise during encoding and input of spatial and non-spatial data. These errors might be for the spatial data in incomplete or double, in a wrong plane, at a wrong scale, distorted, or the spatial data are linked to the wrong non-spatial data. The non-spatial data may also be incomplete or wrong because of typing errors or

field encoding errors. Thus, it is essential to verify the digitized data by editing and correction. Burrough (1986) listed the most common GIS capabilities for data maintenance and manipulation, which is shown in Table 2-4.

Table 2-4. Common GIS capabilities for data maintenance and manipulation

Add/Delete/Change	Interactive editing of the alignment, length, text, text font, and attributes of graphic entities(points, lines and areas as appropriate)
Move/Rotate	Move an entity(point, line, polygon, or group of pixels) to a new position
Stretch/Rectify	Adjust coordinates to fit a true base
Transform Projection	Adjust coordinates to a given scale
Zoom/Window	Enlarge/reduce area of attention
Clip	Cut out area of attention as a separate part
Join/Edge Match	Join two or more adjacent maps ensuring continuity of line and text information across the join
Polygon Overlay and Merge	Intersect two polygon networks to create a new polygon network
3-Dimensional Projection	Create a three-dimensional view of the data (block diagram, usually with hidden line removal
Raster to Vector	Covert (scanned) raster data to a set of lines (vectors)
Vector to Raster	Covert line and polygon data to pixels
Generalization and Smoothing	Data reduction algorithms for changing data structures with scale (e.g. polygon to a point); Removal of excess coordinates in digitized lines
Data Retrieval and Reporting	Simple routines for counting items, reporting areas and perimeters, simple distances, etc.; Simple Boolean search. Results are often written to a text file for further processing

Source: Burrough, 1986, pp.67

2.6.2.3 Data output

Data output is the operation of presenting the results of data manipulation in a form that is understandable to a user or in a form that allows data transfer to another computer system. Burrough (1986) concluded that there were two kinds of data output

forms: common people-compatible data output and computer-compatible output. The former is the common one that is in the form of maps, graphs, and tables; the latter may be in the form of a magnetic tape that can be read into another system, or it may involve some form of electronic data transmission over data communication networks, telephone lines or radio links.

Most GIS will include software for a range of data output options, for example, zooming windowing to selected areas for output; scale and colour change; modifications to text and line fonts, colours, dimensions, etc. Output techniques in GIS mostly depend on the skills developed in the rapidly growing field of computer graphics (for example, Foley and Van Dam, 1982; Giloi, 1978; Mufti, 1983; Newman and Sproull, 1979).

Maps may now be made to any desired level of accuracy and graphic quality-subject to the quality of the original data, and the availability of appropriate computer programs and output equipment (Rhind and Hudson, 1980, pp96-125). Digitizing map data, for example, can have two basic methods of display, based upon vector or raster technology. It is possible to produce output directly on microfilm, ready for projection as slides or as a microfilm film.

In summary, data input, manipulation and data output are the basic procedures to serve for spatial analysis of land use.

CHAPTER 3:

LAND USE POLICIES IN CHINA

3.1 Introduction

This research is concerned with the analysis of trends of land use change and gives special attention to the changes that have been occurring and may happen in the coming decade. Over the past decades China's agricultural policies and urban development policies have changed dramatically. These changes have posed a deep influenced on the patterns of land use. This chapter presents an overview about the changes of Chinese land use policies during different periods and impacts of these policies on land use structure. This overview is to help understand the effects of policy changes of agricultural land use and urban land use on the formation, development and evolution of the rural-urban fringes.

3.2 Land use policies in rural china

During the five decades since 1949, government policies have changed so fast as to render almost impossible an accurate appraisal of their consequences. Some of these policy changes have had significant implications for agricultural development but their motives are not always easy to understand and implementation has been very uneven. Moreover, the statistical data are severely incomplete and the available data

is highly inconsistent. This makes the analysis of agricultural policy particularly difficult. Nonetheless, evidence from a wide range of sources, both official and informal, together with the adoption of the state-of-the-art technology of remote sensing and geographical information systems, may be sufficient to construct a reasonably comprehensive picture of land use and agricultural development of the post-reform period, and the impacts of reform policies.

3.2.1 Land use and agricultural policies at different stages

Agricultural and land use policies have changed directions frequently, but as regards the types of land tenure system, forms of farming and the degree of state control, the policies since 1949 can be divided into two different types. The first type of policy is characterised by increasingly collectivised farming and strict state control of agriculture. This type of policy is observed during the Great Leap Forward (1958-61) and the Cultural Revolution (1966-78). The national policy during the Great Leap Forward presented a strong bias towards industry at the expense of agriculture and in conjunction with flood and drought developed into the most devastating famine in China. The Cultural Revolution resulted in a long period of stagnation in agriculture and farmers' living standards. The second type of policy is characterised by family farming and less state control in agriculture. This type of policy is observed during the land reforms (1949 - 52) and the First-Five-Year Plan (1953-57), the recovery period in the early 1960s (1963-65), and to a much great degree the recent economic reforms (since 1978). During all these sub-periods, the state performed a more balanced development strategy between agriculture and industry, both agriculture and

industry performed much better and the living standards of the people increased much faster than in the other sub-periods (Yao, 1994).

The following sections examine Chinese land use and agricultural policies and their effects on rural economic growth in different economic periods. Section 3.2.2 examines the effects of policy swings on land use and agriculture. Section 3.3 contains an overview of land use controls and land use changes.

3.2.2 Policy measures on land use in rural China

3.2.2.1 Policy context before 1979

China's rural economic policies have changed with the shifting currents of national policies throughout the history of the People's Republic. Much of the literature surveys the pre-1979 policy changes in a chronological order (Yao, 1994; Yao and Colman, 1990). In order to provide the background for the 1979 reforms for this research, this section reviews three main aspects of the pre-reform policies related to land use and agricultural development. The first one is the collectivisation (Zhu, 1991). Until 1949, small-scale, self-sufficient, household farming by peasants and large estate had been typical of Chinese agricultural production for at least eight centuries.

The second aspect is monocrop agriculture (Yao, 1994). Grain production, influencing the ability to feed the population, has been the priority in Chinese agricultural development. This policy frequently inhibited the efficient use of the modest remaining agricultural resources. The result was that the rural landscapes

before 1978 at all levels were heavily committed to grain cultivation and lacked diversification.

The third aspect of the pre-reform policy is capital construction and modern input on farmland (Sicular, 1993). China's development policy has usually emphasised urban industrial growth, with agriculture being treated as a source of inputs for the manufacturing sector. The state has allocated extremely modest investments either directly to agriculture or to the branches of industry that produce modern inputs for agricultural production. Under this investment strategy, the construction of agricultural infrastructure has suffered from insufficient financial support.

To sum up, it must be said that despite the attempts made by the Maoist leadership to improve the natural agricultural resource base and increase the efficiency of farming, a combination of factors - especially policy errors - undermined these attempts. The inefficiency of collective farming was well known. In 1978 Chinese policy makers were faced with a countryside which can best be described as stagnant and where productivity purchase was actually low. Important and immediate reforms were necessary to change this situation.

3.2.2.2 The agricultural reforms after 1978

After 1978, the most far-reaching economic reform was initiated, and is still continuing. The reform introduced a series of major economic shifts, which led eventually to the disbanding of the collective agriculture system and the reduction of

the state's role in planning in favour of a more market-oriented economy (Fukasaku, et al.1994).

The goals of reform policy can best be summarised under two headings: 1) increasing peasant incentive for production - with the household responsibility system as the core policy; and 2) commercialisation of agriculture.

A series of policy adjustment was introduced to the agricultural reforms since 1978 (Powell, 1992). The first was related to the household responsibility system vs. collective farm management. The second was regarded as the relationship between diversified and specialised agriculture. The third reform policy involved in the farming scale. The fourth reform policy was aimed to address the land ownership vs. land usage right dilemma. The responsibility system remains part of the system of public ownership of land in which peasant households and the collective maintain a contractual relationship, with the collective exercising unified control over the use of farmland, large farm machines and water conservation facilities and farmland capital construction.

3.2.3 Agricultural land protection

After the land reform of the early 1950s, the protection of agricultural land was mentioned in the State Construction Land Requisition Measures of 1953, but was not seen as a significant issue. It was given greater emphasis in the 1958 measures (Xu, 1986), but during the Great Leap Forward and Cultural Revolution little attention was given to land conservation, and much good quality agricultural land was lost to

other uses or was wasted as noted in the last section. The 1982 ordinance sought to re-establish some control (Xu, 1986), by updating and revising the 1958 document.

However, while the planning power of local governments is being strengthened, their ability to convert land from agricultural to urban uses is being curtailed. The power for land conversion approval has been transferred to the State Land Administration which was established in 1986 (Wang, 1991, IFTECASC, 1992). In 1953 a county could approve land requisitions of up to 67 ha; in 1958 this was reduced to 20 ha, and it is now down to 0.2 ha. In other words, after 1986, most land requisitions have to be approved by the state authority. This drastic reduction of land approval power, and the corresponding centralisation of decisions about land release, reflects China's serious land shortage, and the government's increasing concern to protect agricultural land. This redistribution of powers is the major agricultural land protection measure in the 1980s acts, (Wang, 1991, IFTECASC, 1992) though previous attempts have also been made to educate and persuade local officials about the importance of conserving agricultural land. However, illegal land conversions still exist especially in the rural-urban fringe.

3.3 Land use and land development policy in urban china

Along with the economic reforms, two notable changes have occurred: decentralisation and the setting-up of markets. In this section, the change of land ownership is reviewed to show how the project-specific type of development by work units has become the dominant form of land development and how municipalities

have regained the control over land through comprehensive development. This is followed by a review on the system of paid transfer of land use rights and the evolution of land development organisation. Following the discussions, different types of land development organisation are examined and their relationships are revealed through paths of and actors at a metropolitan scale.

3.3.1 Land ownership changes

A different policy was adopted in urban area. Although the land ownership of bureaucratic capitalists, war criminals and `anti-revolutionaries' was confiscated by the communists and the People's Liberation Army (PLA) in 1949, ordinary residents were allowed to possess their land because private land was associated with private housing (Wang, 1991). Equalisation of ownership of private property would have been too severe a shock to the society. Thus, private urban land was allowed to co-exist with state ownership, but was not allowed to expand or to acquire rural land. The acquisition of rural land was controlled by the state because nearly all new building was initiated by the state rather than the private sector. Different policies existed in urban and rural areas, i.e. equalisation of rural land and establishment of collective rural land ownership, and co-existence of private and state ownership in the urban area formed a complicated pattern of land development.

Growth of land owned by sectoral departments (1958-82)

Land acquisition and transactions were controlled by the government since 1949 (IFTECASC, 1992). In 1958, the Great Leap Forward was launched. New

constructions, particularly iron and steel works, were built everywhere, occupying a large amount of agricultural land. The following years witnessed a decrease of agricultural output. The loss of agricultural land and uncontrolled growth of urban population became urgent problems on the government's agenda during the three-year depression (1960-1962) (Wang, 1991). To control excessive land encroachment, the State Council amended the Regulation of Land acquisition for State Construction which stipulated that land conversion should follow a specific, detailed procedure. But the policy was not effectively carried out. Primarily, there was no mechanism to measure land use efficiency and to re-allocate land to a better use.

The rate of land conversion charged by the municipalities was low compared to that of land developed by work units because infrastructure investments were cut down and the municipalities were reluctant to invest in the so-called 'non-productive projects' (Gu and Ding, 1995). Limited local revenue was another reason to the slow conversion of agricultural to non-agricultural land. As a result, land occupied by the sectoral department increased.

Abolition of private land ownership and separation of land use rights from land ownership (1982 - present)

The 1982 Constitution (Article 10) abolished the private ownership of urban land and clarified that it all belonged to the state and that rural land was owned by farmers collectively except for the land stipulated by law as state land (Nan and Xiao, 1991). Land ownership thus became uniform in the urban area. A breakthrough was made in 1987 when land use right was separated from its ownership (Nan and Xiao,

1991). The separation of land and housing ownership is a serious loophole in the system. However, it is an inevitable result of a progressive reform agenda. Along with the change of land ownership, methods of organising land development also have changed.

3.3.2 Changes of method of land development

In order to comprehend the significant changes that have been taking place in the urban areas since the economic reforms in 1978, it is imperative to review how land developments were organised after China became a socialist state in 1949(Nan and Xiao, 1991, IFTECASC, 1992). Land development in China can be generalised into the following three main types according to their sequence of appearance.

Project-specific development (used since 1949)

In the 1950s, to speed up industrialisation, the Chinese government adopted a method project-specific development that granted various ministries in the central government the power to organise production activities. In this dissertation, these ministries are referred as the sectoral departments. At the municipal level, various governmental ministries were also set up. In China these governmental ministries were supervised directly by respective units at the central level. At the same time the units formed a municipal government that was led by a mayor. As a centrally planned economy, governmental units at the local level did not really integrate into a locality. The project-specific development proved to be an effective way when the infrastructure was inadequate and many bottlenecks existed. Urban infrastructures were underdeveloped when the People's Republic of China was founded in 1949. The

new government could not rebuild the port cities comprehensively. In an attempt to strengthen the national defence and to reduce regional disparity, development shifted from the coastal region to the inner regions.

Comprehensive development (used since 1978)

Project-specific development caused some problems due to the lack of co-ordination (Gu and Ding, 1995). Projects were managed by various sectoral departments, thus the municipality only involved in the building of city-wide infrastructure. In the late 1970s, the central government decentralised some decision making power to municipalities and empowered them with a more important role in organising constructions (Gu and Ding, 1995).

Comprehensive development (zhonghe kaifa) was the kind of unified development organised by city governments (Editorial Board of China Encyclopaedia, 1988). The city government acquired large tracts of land and constructed urban infrastructure, factories, and service facilities comprehensively. Since developments were organised, a higher efficiency has been achieved.

Comprehensive development generally had two major forms (IFTECASC, 1992). In the first form, the government sets up a development organisation that takes charge of allocating development to or inviting tenders from development companies. Land is acquired by the city government. By doing so, land acquisition can be completed more quickly because of a standard compensation to farmers or other original land users. Then the development companies are responsible for surveying, designing, and preparing land, and construction of roads, water supply, drainage

works, electricity gas supply and communication. When the project is completed the development companies charge development cost and allocates land to various work units. In this way, the development companies are only responsible for land development and infrastructure. In the second form, after land levelling and infrastructure provision, the development companies continue to build house and standard factory buildings for users according to their specific requirements. Then, the buildings and facilities are sold to their users.

Paid transfer of land use rights and real estate market (1987 - present)

A land leasing system has been set up in China since 1987, which is characterised by two features: separation of land use rights from land ownership and paid transfer of land use rights. To encourage efficient land use, land reform was launched. Since the early 1980s (Nan and Xiao, 1991), there was an increasing appeal for the paid use of urban land. Gradually, government began to realise that land resource is a kind of production factor; and that land leasing could let government gain capital to invest in infrastructures. The government has spent money on land acquisition, and now should get the money back to invest in future land development.

The current land development policy in China particularly emphasises that the state should monopolise the primary land market (the State Land Administration Bureau, 1991; Yang, 1993; Research Team of Ministry of Construction, 1993). By "monopolise", it means that each municipality monopolises and controls the supply of land for land leasing (paid transfer of land use) and only land obtained through land sales (conveyance) could transfer its land use rights to other users.. These three types of land development are co-existing at present in China with regional variations. Land

reform is mainly experimenting in coastal regions while traditional methods of land development are still predominant in inner areas. Although land leasing becomes increasingly important in the Chinese cities, project-specific development is still the primary source of land supply to state enterprises in China.

3.3.3 The dynamics of land transactions

Cities develop either through land expansion or redevelopment on existing land. As can be seen in the following discussion, land transactions involve a complex of interactions among farmers, municipalities and land users.

Currently, there are three main types of land ownership's in China (Nan and Xiao, 1991). The first type is rural land that is owned collectively by farmers. The second is administratively allocated urban land that is owned by the state in name but occupied by various state working units. Land is allocated to them through the administrative allocation method (Nan and Xiao, 1991). The third is leased urban land that is owned by the state but the land use rights are transferred to the users through the paid transfer of land use rights. The dynamics of urban land transactions in China can be generalised as the following major types.

Type I_1 - Acquisition of rural land by work units for project-specific development

This is the dominant source of land supply for urban development in China. The typical way to acquire this type of land is through project-specific development. Work units that need land for development can apply for a land acquisition permit

from the municipality. It can then acquire rural land by paying a compensation fee to the farmers. According to the 1986 Land Administrative Act, compensation amounts to three to six times of the average annual agricultural production of the rural land in the last three years before land acquisition (Zhu, 1991). In addition, payments have to be made on the building and agricultural products attached to the rural land at the time of the acquisition. If the acquired land is vegetable land, additional payments have to be paid to a fund set up for developing new vegetable land. Compensation will also be paid if acquisition involves the relocation of people.

Type I_2 - Acquisition of rural land by municipal government for comprehensive development

Municipalities play an important role in this type of land transaction because they directly acquire land from farmers, develop it comprehensively and then allocate it to users. This type of transaction was mainly initiated after 1978 (Nan and Xiao, 1991). The purpose of this comprehensive development to deal with land acquisition more efficiently and more quickly, because the municipality, instead of the users, acquires the land from farmers through a standard compensation fee. Negotiation with the farmers could proceed more easily and community facilities could be shared by several work units. By obtaining land from the municipality, the price of housing could be relatively low because the development companies only need to pay the farmers compensation for agricultural land rather than land price for residential land that is more expensive. However, like the former type of land, the user can only use the land but cannot transfer it freely to other users, especially to foreign buyers.

Commercial housing built on this type of land is mainly for domestic use in contrast to commercial housing built on leased land that can be used by both the domestic and foreign buyers. Comprehensive development, originated from the co-operation of several work units to build shared housing apartments, is thus a kind of development that involves preliminary market mechanism, i.e. a property market without a land market.

Type I_3 - acquisition of existing administratively allocated urban land for urban infrastructure by municipal government

Usually this type of transaction is for the development element of the urban infrastructure (Wang, 1991). The municipal government negotiates with the occupier of the previous administratively allocated land that is required for the construction of urban infrastructure. Theoretically, land is owned by the state. As this type of transaction only involves the change of land users that might both belong to the state, thus no compensation is needed. However, as mentioned above, sectoral departments have paid compensation to farmers and paid the cost of levelling and formation of the land. Thus, the municipal government needs to compensate the users for their losses and needs to allocate another piece of urban land to them in exchange.

Type II_1 - Acquisition of rural land by municipal government for land leasing

This is the most recent type of land transaction and is becoming increasingly popular. Rural land is acquired by the municipality and then leased to a user through the market mechanisms of negotiation, tender and auction (Nan and Xiao, 1991).

Monopolising the right of supply of this type of land, each municipality can acquire land at a standard price from farmers and sell the land to a developer at a market price. Considerable profits can be made by the municipality because of the great difference between the land acquisition price and the land lease price (Nan and Xiao, 1991). As land obtained from land leasing is more expensive than the previous three types of land, most users try to avoid acquiring land through land leasing as far as possible. The current customers of this type of land transaction are mainly foreign investors (Wang, 1991). The purpose of development is mainly for commercial housing, offices, hotels, and standard industrial buildings. However, it has been reported that municipalities are facing increasing resistance from farmers who sometimes even resort to violence when they begin to know that the land will be leased out at a much higher price. They are demanding higher compensation because the municipality can obtain a higher price in the land market through land leasing.

Type II_2 - Acquisition of existing administratively allocated urban land by municipal government for land leasing

Municipalities acquire the previously administratively allocated urban land that is occupied by work units and then lease the land to a user who can pay a market land price (IFTECASC, 1992). Unlike type I_3, in which the land is mainly used for urban infrastructure construction by the municipal government for a non-profit use, this type of transaction, the same as the type II_1, is quite profitable. Compensation to the original users is higher than type I_3, because it is difficult for the municipal government to justify the payment at the same price as land acquired for state

construction. As for land acquired for state construction, the socialist principle requires that local interests should obey national interests and that individual interests should obey community interests (IFTECASC, 1992). Under this principle, users are often asked to make sacrifices for the construction of state projects and community infrastructure. However, it is not applicable to this type of transaction. Negotiations have to be carried out between the original land user and the municipality until a compromise of profit sharing is reached. It is hardly surprising that some city governments have to lease out their own compounds that are usually located at the city centre and move their offices to other places. Surely, it is more expensive and difficult for municipalities to assemble this type of land than the type II_1. This explains why leased land mainly comes from acquisition of rural land and unoccupied urban land and why Economic and Technological Development Zones (ETDZ)s that need large tracts of land are located at the periphery of an urban area(Gu and Ding, 1995)

Types II_1 and II_2 transactions are referred as the primary land market in China. Municipalities acquire land from the rural areas (Type II_1) or acquire existing administrative allocated urban land occupied by various work units (Type II_2) and then transfer the land use rights to users through land leasing in the forms of negotiation, tender or auction.

Type III - Exchange of administratively allocated land among work units

Work units can exchange their administratively allocated land through negotiations (Nan and Xiao, 1991). For example, one side may offer the other side

some housing as a term for exchange. The exchange, however, does not follow market prices. Because of the lack of information and standard practice, such deals are based on negotiation. Exchange of land through this avenue is very time-consuming, and it is difficult to balance the demand and supply and to settle compensation.

Type IV - Transaction of leased land among land users

Only land that is acquired from the primary market can be transacted, i.e. leased land. This is referred to as the secondary land market in China (IFTECASC, 1992). In newspapers and government documents, this type of transaction is sometimes further divided into transactions of land use rights among real estate companies and transactions among ordinary users. The latter is referred as the tertiary land market (Zhou, 1992). Because the prices of land acquired from negotiation, tender, and auction differ greatly, some cities suggest that inter-transactions of land obtained from negotiation, tender, and auction should not be allowed. However, this has not become a standard practice yet.

Basically, the process of decision making is still largely based on the administrative system that decides the location and amount of land that will be put onto the market. Market mechanisms only operate on leased land and do not affect most of the land that is administratively allocated. Such a feature is significantly different from that of cities in Western countries where most land is privately owned under a freehold system. In Western cities, governmental intervention through urban planning is a secondary process, which attempts to correct market failures.

3.4 Conclusion

Through the review on the land use policy in this chapter, the transition of the land use policy whether from the rural land use to urban land use or vice versa has been taking place deeply and thoroughly since 1949, not least during the two decades of the post-1978. The three main aspects of the pre-reform policies, that is, collectivisation, monocrop agriculture, and capital construction and modern input on farmland, are closely related to land use and agricultural development before 1978, which brought about great influences on the land use between rural land use and urban land use. Afterwards, the most far-reaching economic reform introduced a series of major economic shifts, which led eventually to the disbanding of the collective agriculture system and the reduction of the state's role in planning in favour of a more market-oriented economy. Accompanying with the economic reforms, two notable changes have been decentralisation and the setting-up of markets. At the same time a different kinds of policies were adopted in the urban area of China. This leads to the all-facets changes on the land ownership, land use methods and land transactions. I_2 and II_1 are the two types of land transaction that have happened actively in rural-urban fringe in China's cities where rapid urbanisation are taking place.

CHAPTER 4

STUDY AREA

This chapter mainly analyses the general background factors, which have impacts on the land use changes in a rural-urban fringe like Tianhe District. In the broad context of Guangzhou municipality, its location, physical condition and socio-economic development history are discussed, followed by a general background for the analysis on land use changes in Tianhe District. Then the general factors influencing the land use changes in the whole Guangzhou's municipality are discussed in detail, focusing on their impacts on the land use changes at different stages of development.

4.1 The general background of Guangzhou Municipality

Tianhe District as part of Guangzhou municipality, is a result of China's 'Open-door and Reform' and the development of the Guangzhou Municipality. It is a potential area for Guangzhou eastward sprawl along the development belt of the Pearl River, and the future city centre of Guangzhou (BPGM, 1991). Consequently, before the basic circumstances can be discussed, it is necessary that some issues about Guangzhou be put forward, including the historical development trends, location advantages, the evolution of Tianhe District from the agricultural belts in the past to

the rural- urban fringe at present, and being the possible future urban centre.

4.1.1 Location

Guangzhou, located in the Pearl River Delta of Southern China, has long been the gateway of China's link to the outside world (Figure 4-1). Situated at the confluence of the East River and North River of the Pearl River system, the city is mainly built on the upper part of a drowned valley that extends southwards to Human, a small town in the south part of the Pearl River Delta (Xu, 1985). Guangzhou enjoys many favourable natural conditions. The river system provides a cheap, convenient way of transportation. The southern sub-tropical climate supplies the Pearl River Delta with rich agricultural products. The delta has long been a densely populated area.

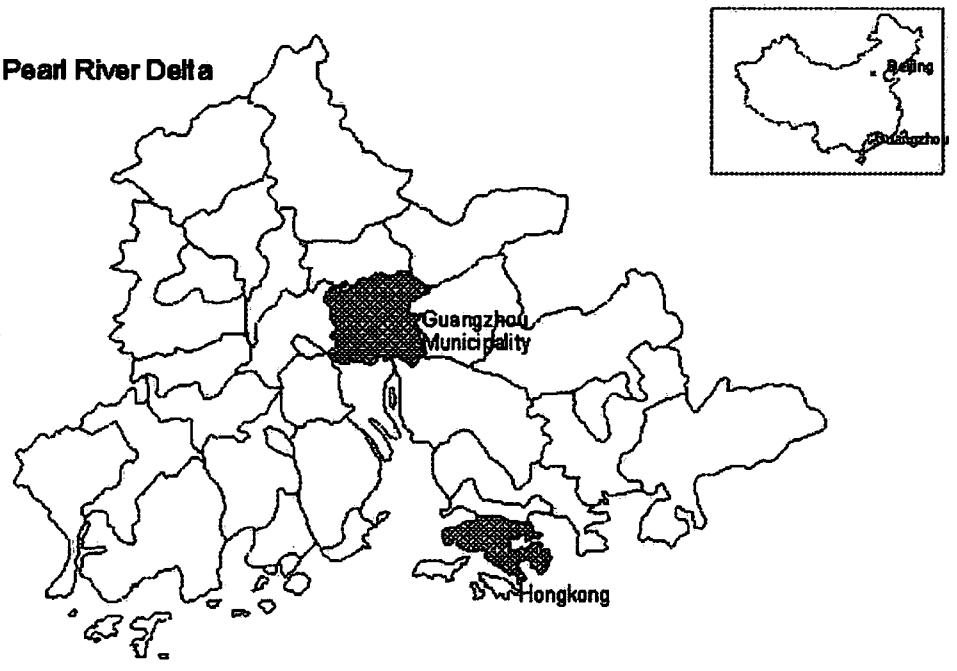


Figure 4-1. The Location of Guangzhou Municipality in the Pearl River Delta Area of Guangdong Province

Guangzhou is located between the longitude 112°57' to 114°3' and altitude between 22°26' to 23°56'. The total area of Guangzhou municipality is 7,434.4 km^2 occupying 4.2 % of surface area of Guangdong province. In 1993, the city is comprised of 8 Districts, 3 counties and 1 county-level city. The eight Districts in the city area were Yuexiu, Dongshan, Haizhu, Liwan, Tianhe, Baiyun, Huangpu, Fangchun (BPGM, 1993)(Figure 4-2). The first four were urban districts while the latter four were suburban districts. The four counties were Hua, Conghua, Zengcheng, and Panyu city. The eight districts totally constitute the *city area*, while the Guangzhou Municipality was the *city-region*. The area of the city area was 1,443.6 km^2 occupying 19.42 % of the city-region. It reveals that the city area occupied only a small percentage of the total area under the jurisdiction of the municipality. The structure has been set up since 1984 when counties nearby were put under the jurisdiction of the city. The number of counties that a city can have is usually arbitrarily set. The area of the present study is confined to the city area.

The Guangzhou area is in south of the north tropical line and belongs to the subtropical monsoon climate. It possesses the following characters. First, the climate is warm and hot and its annual average temperature is 21.8 ^0C; the average temperatures in January and in July are 13.3^0C and 28.4 ^0C respectively (BPGM, IGI and NIG, 1992). Secondly, the sunshine is long and light energy is plentiful. Its sunshine time is about 1906 hours per year and annual average sun radiation is about 106.7 km carol per square centimeters; Thirdly, it has plentiful rainfall with annual average rainfall of 1694.1 km respectively (BPGM, IGI and NIG, 1992); Fourthly, it has alternate monsoons. Generally, from September through March in the next year is

the north wind while from April to July the wind turns in the Southeast direction and the East wind happens in August; Fifthly, the disastrous climatic events take place frequently, for example, cold waves, typhoons and rainstorms.

4.1.2 Socio-economic background

At the end of 1997, the total population of Guangzhou Municipality (the city-region) was 6.12 millions in which the non-agricultural population was 3.56 million. The total population of Guangzhou City area was 3.67 millions in which non-agricultural population was 2.99 millions. The city area of Guangzhou is a highly urbanized area. Although the city area only accounted for 19.42 % of the total land under the jurisdiction of the municipality, its population occupied 59.98 % of municipal population because the city area was densely populated. The population density of the municipality reached 823 persons per km^2 while the city area reached a density of 2,544 persons / km^2 (BSGM, 1993) In some urban districts, population density was as high as 52,674 persons / km^2 (BSGM, 1993).

Before the economic reforms, Guangzhou's development was slow because it was not located in the strategic regions of national investment. After the economic reforms and the implementation of the open door policy, the growth rate of Guangzhou's economy has increased and its status in the national urban system greatly raised. Flexible and favourable policies have been granted to Guangzhou Municipality by the state. Various reform programmes have been experimented with in Guangzhou Municipality; for example, it was one of the first cities to lease urban land to foreign investors. New economic policies have stimulated Guangzhou Municipality to increase

its productivity, to find external resources and investments and to improve the infrastructure. As a city in southern China that is close to Hong Kong, Guangzhou attracted foreign capital and introduced management skills under a market economy. Investment sources in Guangzhou are thus more diversified than those in the other interior industrial cities that relied heavily on state investment. The economic structure in Guangzhou has changed. The rapid growth of the tertiary sector produced an increasing demand for commerce and office land. Economic freedom has led to a proliferation of non-state ownership. With the changes in land development organisation, the municipality's control over land has been greatly increased while on the other hand, the incentives to unregulated land use changes have been created, in which the existing land users try to capture the different land values and price differences of the administratively allocated land and leased land.

4.2 The general background of Tianhe District

4.2.1 Location and topography

Tianhe District is located at the east of the old Guangzhou Municipality and is on the rural-urban fringe (Figure 4-2). It is kept apart by the Pearl River from Haizhu District in the south. It is surrounded by the mountain area of Baiyun District to the north, Huangpu District to the east, Dongshan District to the west. The Tianhe area has its the maximum length of 17.5 km in the east-west direction and 15.75 km in the north-south direction (BLATD, 1994)

In terms of administration, Tianhe is a new district. Befroe 1983, the Tianhe together with Baiyun District was part of the old district, called Suburb District.

According to its topography, Tianhe District can be divided into three regions: the north part is the low hill area of magma rocks with an altitude of 200 to 400 m above sea level; the middle part is the platform area of metagraphic rocks with an elevation of 40 to 50 m; and the south part is the floodplain of the Pearl River, with its elevation of 1.5 to 2 m.

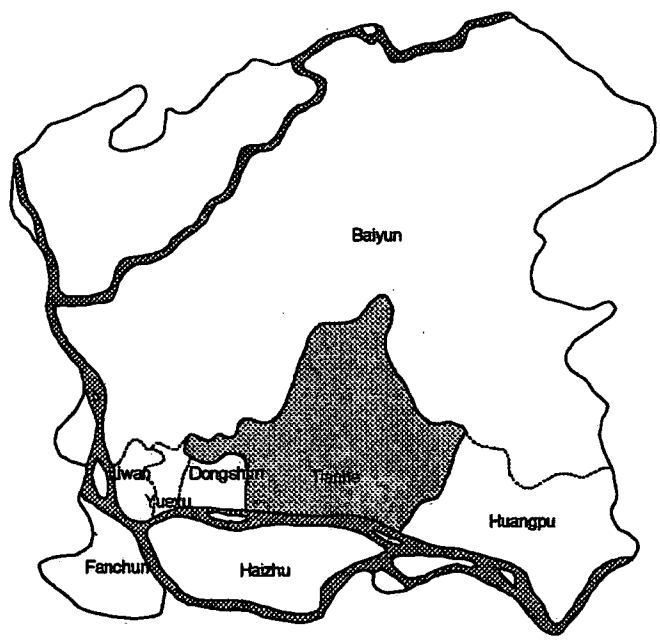


Figure 4-2. The Location of Tianhe District in Guangzhou municipality

4.2.2 Social economic conditions

Tianhe District was set up in 1985, including two towns and 7 sub-districts (BLATD, 1994). The land area of these towns and sub-districts are listed in Table 4-1.

The location of the towns and other geographical positions discussed in this dissertation can be seen in Figure 4-3.

Table 4-1. A list of land areas of the town and sub-districts under Tianhe in 1993[1]

Towns and Sub-districts	Areas(ha)	Area(sq. km)	%
Total	14777.4	147.77	100.00
Shahe town	5864.7	58.65	36.69
Dongpu town	5199.3	51.98	35.18
7 Sub-districts	3713.4	37.14	25.13

Source: BLATD, 1994

In comparison with the four districts in the old city, Tianhe has a lower number of urban residents, a lower population density, but a higher agricultural population. This character manifests that Tianhe is a rural-urban fringe and a place that is experiencing urban expansion and population movement across the area.

Table 4-2 shows the population in Tianhe District. It is apparent that Tianhe in 1993 is mainly composed of non-agricultural population while the agricultural population is still only one fifth as much as the non-agricultural population (BSTD, 1993). Moreover, the non-agricultural population concentrates in the 7 Sub-districts while the agricultural population largely resides in Shahe and Dongpu towns. The temporary residential population in Tianhe is about 110,000 (BSTD, 1993).

[1] Data in this table are drawn from the Report of Land Use Situation of Tianhe District. The calculation results in this research are different from data of the above table. The major reasons are the differences of calculating regional scopes between the Tianhe Report and this research. The former made a statistical 'flying area', which data deducted some land area belonged to other administrative regions and added land area outside but belonged to Tianhe District. This research did not consider the factor of 'flying land area', that is, only calculating the land area in the administrative boundary of Tianhe.

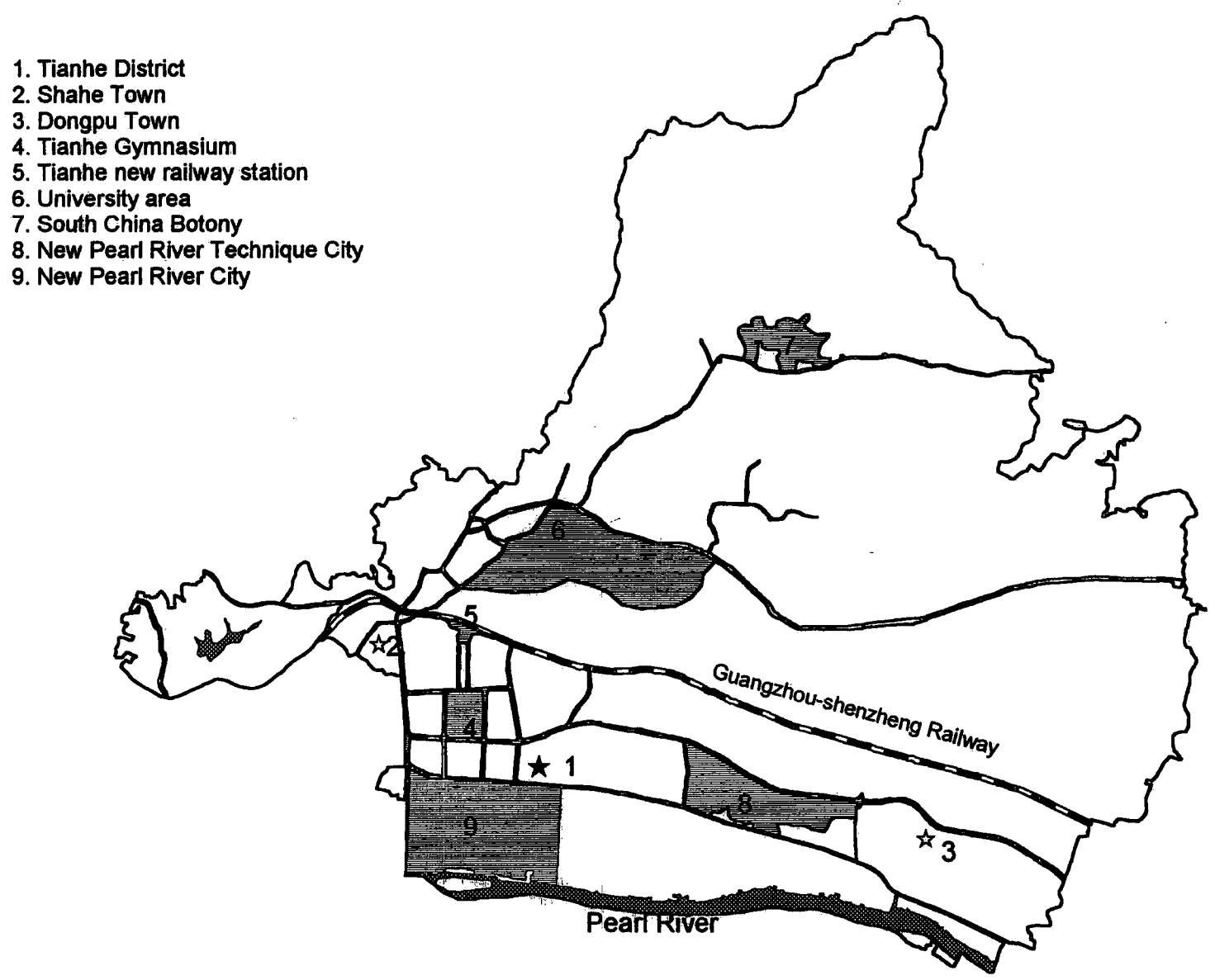


Figure 4-3: Sketch map of some important location in Tianhe Distict

Table 4-2. Tianhe population, 1993

Units	Permanent population (person)	Of the total(person)		Temporary residential (person)
		Non-agricultural	Agricultural	
Total	375906	312865	63041	110554
Shahe Town	78896	52592	26304	
Dongpu Town	36142	13276	22866	
7 Sub-districts	260868	246997	13871	

Source: BSTD, 1993, p6

On the employment side, unskilled labour in Tianhe is the largest category, and the second is different specialist and technicians (those with the middle and advanced range are more than 20,000); the third are the farmers in the plant, forest, husbandry and fishery industries. In addition, there are large number of academics in Tianhe (BSTD, 1993) because it is favourable for the development of high-tech industry.

The investment environment in Tianhe is also pretty good and its economy has developed rapidly. In 1993, the social gross output value amounted to 3 billion RMB and the GDP was 1.16 billion RMB; the gross industrial and agricultural output value was 2.1 billion RMB (of this, gross industrial output value was 1.965 billion RMB and gross agricultural output value 0.131 billion RMB) (BSTD, 1993). In terms of the wage income, staff in urban area earned 5,100 Yuan per person annually and farmer's net income was 10600 Yuan per year per person (BLAD, 1993).

4.3 Land use change and economic development

4.3.1 The transformation of Guangzhou's economic structure

The development of Guangzhou benefits from the fertile Pearl River Delta as its direct hinterland. The Delta has fertile soil and plentiful freshwater, thus is famous for its fishery, silk-mulberry, subtropical fruits, sugar, vegetables and flowers. The delta supplies Guangzhou with raw materials for light industries and receives industrial products and services from the city (Nan and Xiao, 1991). From the core area, Guangzhou's economy also extends outwards across southern China

Perhaps the most critical factor for Guangzhou's flourishing growth after the economic reforms and the open door policy is its proximity to Hong Kong and Macao (Figure 4-1). Guangzhou has long been the `southern window' of China. Since the winter of 1956, Guangzhou has hosted the biannual China Import and Export Commodity Fair which till 1978, was the only channel for China's foreign trade (Xu, 1985). After the economic reforms, Guangzhou enjoyed flexible and favourable policies in economic decisions and in absorbing foreign investment. Foreign investment injected a new vitality to the city and stimulated the development of markets. Its economic growth rate was faster than other coastal cities such as Shanghai and Nanjing. The agricultural population around Guangzhou has been gradually transformed into an urban population. Farmers whose land has been acquired by state constructions are eligible to become urban residents. Rapid encroachment of rural land thus increases the urban population of Guangzhou.

Along with industrialisation, the level of urbanisation increased, although the rural-urban migration was still controlled through a household registration system (Nan and Xiao, 1991). The composition of GNP of Guangzhou shows that the city has

changed from an agricultural economy to an industrial economy. The contribution of the agricultural sector in GNP has been decreasing steadily (Liang, 1996). The contribution of manufacturing sector in GNP increased after 1949 but began to decrease after the economic reforms. The tertiary sector has been constrained after 1949 because the socialist officials believed that the sector was unproductive (Liang, 1996). After the economic reforms, the tertiary sector became the most dynamic sector in Guangzhou (Liang, 1996). Both foreign trade and domestic trade are prosperous due to the open door policy.

Eventually in 1990, the tertiary sector surpassed the manufacturing sector in terms of GNP for the first time (Liang, 1996). The structure of the manufacturies sector has also been upgraded. Within the light industries, the proportion of industries based on agricultural products was constantly decreasing which means that the growth of light industries has relied more on non-agricultural materials.

4.3.2 The impacts of transformation on land use

The transformation of the economic structure has led to impacts on the changing urban process (IFTESAC, 1992). First, due to the emphasis on industrialisation, industrial sites have been opened in the suburbs. In the 1950s, a number of factories were set up through a project-specific way of development in the urban fringe. And later the vacant land between the industrial sties was filled. Thus, a belt of industrial land use surrounded the city proper. Second, the growth of the tertiary sector in the 1980s generated a huge demand for office buildings, shops, hotels and others service

facilities. Also, the decentralisation of decision making from the government to companies accelerated the trend. Headquarters of foreign companies have been set up in the city centre. The change of the economic structure was one of the engines that restructured the residential land uses in the city centre into commerce and office uses.

4.3.3 The basic changes of land development organization in Guangzhou

Along with the transition to a market economy, the organisation of land development has experienced important changes. The issues that are particularly relevant to Guangzhou are discussed here. Before the economic reforms, the political economy of China maintained a highly centralised process of decision making. Localities could not play an active role in land development. Development was organised on the basis of projects that were directly controlled by the economic planning system. Actual land acquisition was conducted by various work units themselves. Only nominal approval was obtained from the municipal government (Liang, 1996). Land allocation was based on administrative methods and used inefficiently. Over-occupation was a common phenomenon. The most significant change in organisation of land development was that municipalities began to control land development and a land market was established. In the beginning of the 1980s, the National Construction Commission (NCC) recognised the problem and encouraged `comprehensive development' in which municipalities could play a more active role in land acquisition and allocation. Receiving the circular issued by the NCC, Guangzhou municipal government decided that the piecemeal way of land allocation would be stopped (Liang, 1996). Land development began to follow the principle of comprehensive development. Before construction, there should be a unified plan and

design. The development works should be undertaken by a single construction unit and managed directly under the municipality (CCGM, 1987).

4.3.4 The factors in relation to the changes of land development organization

Four aspects of changes have been initiated.

First, to control rampant occupation of agricultural land, land allocations began to be controlled by an annual plan (CCGM, 1987). Before 1987, there was no plan to control the total amount of land allocation. Each work unit negotiated with farmers to acquire land for construction. Along with rapid economic growth, the occupation of arable land became a serious problem in the early 1980s. The loss of land led to the decrease in food production. Since 1987, the acquisition of arable land has been controlled by an annual plan issued by the state. From 1987 to 1990, on average 600 ha. per annum of arable land were allocated to urban construction for Guangzhou. Due to the tight control, the actual acquisition of arable land only reached an average of 400 ha. per annum (Chang, 1996).

Secondly, since 1979, comprehensive development has been encouraged to replace the traditional project-specific development. Users are now required to buy developed land or housing from development corporations. From 1986, comprehensive development began to be adopted in industrial and commercial development as well (Nan and Xiao, 1991). The scale of development under the comprehensive development is larger than that under the traditional way of development. Thus, service facilities can be more efficiently provided.

Thirdly, a land market has been set up since 1990 (Chang, 1996). The paid transfer of land use rights became an important way of land development. From 1987, a land use fee was charged. The municipal government announced that a land use fee would be charged on foreign corporations and joint ventures. In 1987, the occupation of arable land began to be charged with additional fees (CCGM, 1987). In 1989, an urban land use fee was charged on all land users (Liang, 1996). In 1990, three pieces of land were transferred through payment in Guangzhou. These three pieces of land were located along the Dongfeng road in the city proper, in the north part of the city leading to the airport and in Tianhe District, occupying land areas of 2,968 m^2, 17,191 m^2, and 21,887 m^2 respectively (Chang, 1996).

Fourth, to strengthen the control of land development by the municipality, the procedures of land development application have been changed (Chang, 1996). Since land development involved many issues, for example, fire protection, greening, preservation of historical relics, work units had to seek approval from many government departments before adoption of the new system. The process was rather time-consuming. In actual implementation, the approval system was not effective because of the lack of monitoring. A new system, using so called 'professional applicants' has been developed since 1989. The professional applicants are usually planners in planning and design institutes who are familiar with regulations of buildings and planning and who are responsible for the design of the project (Nan and Xiao, 1991). It is the responsibility of the `professional applicants' to apply for the permits of construction from the government for the users or developers. Thus, the project design team and planning authorities can communicate better. The adoption of this policy encourages comprehensive development.

Changes in land development organisation have greatly increased the power of the municipality to control land development. Since the adoption of the system, rampant occupation of agricultural land has been restricted. However, the problem has not been thoroughly solved. Since 1991 the problem has begun to re-emerge. Two reasons are attributed to the phenomenon. First, foreign investment became increasingly important not only in industrial development but also in real estate development. The municipality attempts to attract foreign investment by relaxing planning controls, simplifying application procedures, and the provision of cheap land. Second, closely related to the policy of attracting foreign investment, a new growth strategy has been put forward by the municipality. The strategy attempts to 'build Guangzhou into a world city' by a generous provision of construction land (BPGM, 1991). In the eastern area of the city, numerous development zones have been set up. Establishment of a land market stimulated dynamic land use changes. This is because there was a huge price difference between the administrative and market allocations. The municipality can almost compulsorily purchase rural land at a very low cost. Leasing land thus can bring about land premium to increase local revenue. The huge price difference also leads farmers to change their land uses through the black market which creates the problem of unregulated land use changes (Liang, 1996).

4.3.5 Land use change in Guangzhou and the development of Tianhe District

In the context of historical analysis, the policy changes have posed much great influence on the land use changes in late 50 years since the establishment of the People's Republic of China. From 1952 to present, four change stages can be divided clearly, that

is, a stage of industrialisation (1952-59); a stage of constrained extension (1960-1978); stage of urban fringe growth and emergence of sub-centre (1980-87), and stage of urban sprawl, land use restructuring and the formation of sub-centres (1988 - present).

1) Stage of industrialisation (1952-59)

There was a period of rapid urban expansion of Guangzhou in the 1950s. In this period, many factories were set up in the suburbs. The urban growth policy put forward by the Guangzhou Congress in 1954 was to `change the consuming city into a productive city' (Liang, 1996). As it was located in the coastal frontiers, Guangzhou was unable to receive intensive state investment. Industrialisation had to rely on limited resources. As a result, Guangzhou was not able to set up large industrial areas but only those rather scattered industrial sites. It was obvious that each factory had to build its own residence under this type of industrial development. In 1958, industrialisation became the overwhelming task of urban development. A policy of `transforming Guangzhou into the industrial base of southern China' was put forward (Liang, 1996). The priority of land development was industrial use.

In this period, the major form of urban expansion was the transformation of the agricultural land use to industry and housing for its employees. Although some factories were built up at Yuanchun, on the border between Tianhe and Huangpu Districts, and some universities and research institutes were set up in the north part of Tianhe, the whole Tianhe District was still a purely rural area. The old airport in Tianhe was to be demolished and the area was reserved for large sports centres and recreational parks.

2) Stage of constrained extension (1960-1978)

After the Great Leap Forward, especially during the Cultural Revolution (1966-1976), China entered a period of economic recession. Workers recruited from rural areas were sent back so that the food supply by the Government could be reduced. The annual allocation for urban construction was heavily reduced and maintained at a low level. In the structure of land allocation, industrial development was less predominant although it still occupied a large proportion. Instead, due to the policies of national defence of the Chinese leaders in the international political environment, the land allocated to national defence increased significantly and maintained as a large proportion untill 1982. This is because Guangzhou was located in the coastal frontier and is the headquarters of one of the PLA's eight Military Regions.

At this stage, because investment in infrastructure was purposely reduced, land development projects had to rely on the city proper for services. The urban growth policy stated that demolishing old housing should be avoided and new construction was encouraged to build on vacant land within urban areas. However, at this stage, the rate of economic growth was low. Urban construction was disturbed by political turmoil and movements. The expansion of the built-up area did not follow the axes into suburban counties. Rather factories were built not very far way from the city proper. Except for a few construction projects taking place in clusters, land development generally surrounded the urban built-up area and extended at a constrained pace.

3) Stage of urban fringe growth (1980-87)

This stage largely inherited the characteristics of the previous one. However, because economic reform had been initiated, there were some changes in the urban

spatial structure. For example, the comprehensive development encouraged the growth of large residential communities in the urban fringe. The construction of the Five-Lamb New Town in Tianhe District is an example (Liang, 1996). However, because land reform had not been initiated, urban redevelopment was still hindered by the lack of differential land values. The construction sites were more concentrated than those after the land reform. The Guangzhou Master Plan put forward a multi-nuclei structure for the city which stimulated the development of urban fringe (BPGM, 1991). The Tianhe District began to attract investment. The master plan suggested that the city should extend towards the Huangpu District along the shore of the Pearl River consisting of three parts from east to west (BPGM, 1991). Green belts would be preserved between these parts to prevent the formation of a whole agglomeration, while convenient transport networks would connect these parts to form an organic metropolis.

In the master plan, Tianhe District was selected to develop education, scientific research and a sports center which was prepared for the 6th National Games, which comprehensive service and entertaining facilities would be set up; a scientific and technological research park was proposed.

4) The stage of urban sprawl, land use restructuring and the formation of subcentres (1988 - present)

In Guangzhou, urban expansion was slow from 1960-1978 because of the relationship between job and residence as a result of state housing provisions and a dominant mode of public transportation (Liang, 1996). Except relatively independent industrial sites in the suburbs, suburban areas have maintained a rural landscape and

functionally provided vegetables and non-staple food for the city. Yet, after the economic reforms, particularly the land reforms, the expansion of urban built-up area has been quickened. This is a sign that urban sprawl has begun to emerge in Guangzhou. Evidence suggests that in 1980s, industrial decentralization took place at an unprecedented pace. If the metropolitan Guangzhou is divided into four zones, i.e. central core, inner fringes outer fringe and suburban counties, it can be seen that the central core lost industries both in terms of the number of factories, value of fixed assets, and workers and staff (Table 4-3). The inner fringe also lost factories but at a smaller rate. The outer fringe and suburban counties have gained industries.

Table 4-3. Decentralization of industrial sites in Guangzhou, % of total

	Number of Factories			Value of Fixed Assets			Workers and Staffs		
	1980	1989	changes	1980	1989	changes	1980	1989	changes
The Central Core[a]	38.37	27.19	-29.14	27.67	33.76	-17.74	37.51	26.21	-30.13
Inner Fringe[b]	24.93	23.48	-5.82	41.00	34.91	-14.85	36.68	35.08	-4.36
Outer Fringe[c]	10.29	15.29	48.59	20.22	26.83	32.69	13.59	18.59	36.79
Suburban Counties[d]	26.41	34.03	28.85	11.11	15.50	39.51	12.23	20.12	64.51

a. refers to the Dongshan, Yuexiu, Liwan Districts; b. refers to the Fangchun, Haizhu Districts; c. refers to the Baiyun, Tianhe, Huangpu Districts; d. refers to Hua, Conghua, Zhencheng, Panyu city.

Source: Hu, 1993, p.41.

As population density was extremely high in the old city areas, land use restructuring occurs in Guangzhou. Land use restructuring involves the emergence of new land uses, urban renewal, and the change of land uses without demolishing old buildings (Hu, 1993)

A typical example for the emergence of new land uses is the construction of Guangzhou Racecourse which is located on the east of Tianhe District . Horse racing

has been criticized as a bourgeois way of life and forbidden for almost half century (Liang, 1996). As the political atmosphere become less ideological and more pragmatic, perhaps under the influence of Hong Kong, Guangzhou began to consider building a racecourse in the eastern suburb. The modern racecourse, 850 metres long and 378 metres wide, is located beside the Huangpu Avenue in Tianhe District and designed to accommodate twenty thousand spectators. The racecourse is equipped with modern facilities such as cable television, a news centre and a computer centre in charge of lottery tickets.

The formation of subcentre in Guangzhou is due to the establishment of Guangzhou Economic Technological Development Zones (ETDZ) (CCGM, 1996). The proposal to establish the Guangzhou ETDZ was formally approved by the State Council in December 1984. It is quite a success in terms of the output value of products, profit level and foreign exchange earned. In 1992, the gross value of industry output (GVIO) reached 2,479 million RMB, a 14 per cent increase compared to the previous year (BSGM, 1993). The joint ventures achieved 2,283 million RMB of output value accounting for 91.7 per cent of the total. The net profit reached 127 million RMB. The foreign business companies exported US$128 million accounting for 56.5 per cent of the zone. The actual utilization of foreign direct investment was US$34.08 million. Through intensive investment, the Guangzhou ETDZ has been well equipped with infrastructure such as electricity, water supply, road, sewage and drainage (Liang, 1996)

The growth of Guangzhou ETDZ has been quickened in 1992 when a Guangzhou Duty-Free Zone (GDFZ) was permitted by the State council (CCGM, 1996). The GDFZ is located inside the Guangzhou ETDZ and acquired 1.4 km^2 of land area. Besides the Guangzhou ETDZ, there are more development zones coming up. The

Tianhe High-Tech Industrial Zone and Nansha Economic Development Zone were approved by the State Council in 1992 (CCGM, 1996). In the same year, the municipality set up three more ETDZs, namely Hua ETDZ, Dongsha ETDZ at the Fangchun District, Yunpu ETDZ at the Huangpu District. These zones change the urban structure of Guangzhou and are vital to the future growth of the city.

4.4 Conclusion

To sum up, Tianhe District is one of the typical urban-rural fringe areas of Guangzhou, which has traditionally been a monocentric city. Originally, urban development was concentrated on the north shore of the Pearl River. Although industrial sites were built in the 1950s, urban form was still quite compact since these independent sites only occupied a very limited proportion of population and land. After the economic reforms, with the rapid economic development and population growth, the city needs much more development space. Tianhe District is becoming one of the major districts of Guangzhou Municipality with an advantageous physical, socio-economic condition and location.

The city centre of Guangzhou municipality and the Tianhe District are not very far from each other. Convenient transportation network links the two together. So, the Tianhe District, attached to the main city area, is no long a suburban centre. If the revised master plan is carried out in 2000, it can be foreseen that the built-up area of Guangzhou will extend quickly towards the northern suburban counties. A new international airport for Guangzhou will be built in the Huashi further north. As

mentioned above, a number of small cities will be built and the city will evolve towards a further decentralized pattern.

CHAPTER 5:

METHODOLOGY AND DATABASE DEVELOPMENT

5.1 Research strategy

In this chapter, the emphasis will be placed on discussions of how the GIS tool is applied to the analysis of policies and socio-economies and their impacts on changes of land use patterns. This includes the determination of research methods, data collection, and analysis of spatial data.

This chapter outlines the methods used in this research, and includes technical issues related to database development and spatial analysis. In order to realise the aims of this research, a suitable methodology had to be applied. It includes three stages of study. Stage 1 involves details of what kinds of data have been collected. At stage 2, data captured from the original maps are digitised into a GIS. This involves data preparation, coding, digitising and table data input, and data correction. At stage 3, the database is further developed and a series of maps are extracted and overlaid as required to meet the needs of further spatial analysis. The relationship of these three tasks can be seen in Figure 5-1.

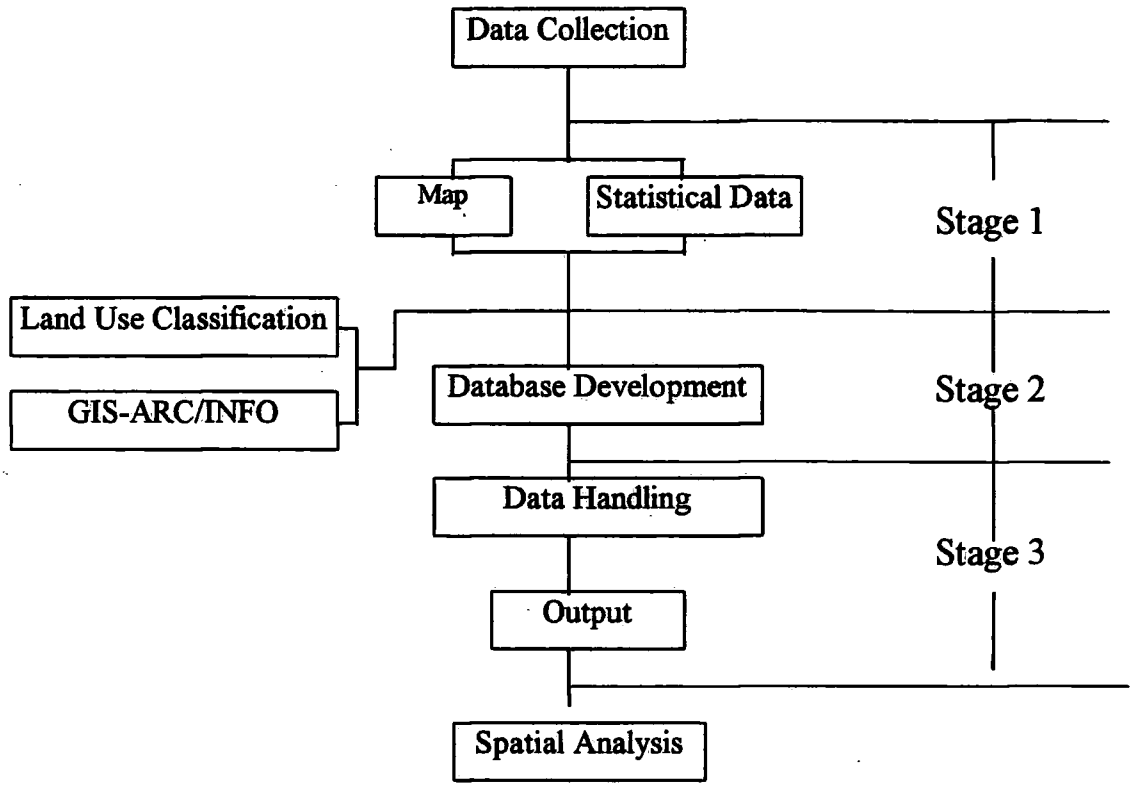


Figure 5-1. Framework of database development and data analysis

5.2 Data used in this research

In order to attain the main objective of this thesis, it is important both to gather relevant information, and to understand its nature and reliability. To fulfil the analysis required in this study, data were collected during extensive fieldwork in July- October 1997. Most of the data was obtained from local government.

As mentioned earlier, the chosen area for land use study was Tianhe District. As regards the rural-urban fringe area like Tianhe, land use data from historical

periods needed to be collected: this allows a comparison of the changes of land use pattern affected by socio-economic development, demographic changes and land use policies. Unfortunately, data collection is quite sensitive in China. Logically, the government is responsible for almost all of the data collection, statistics and data handling. In practice, the different authorities of the government collect the data at different times using their own unique standards. Far worse is the fact that they regard these data as 'private', i.e., owned by the authorities that have collected them. It is crucially important to classify and capture the data through a standardised method. Although there are volumes of data available in this field of research, the following data were selected due to its accessibility.

The only official land survey in Tianhe District, which was commissioned by the National Bureau of Land Administration (NBLA), was carried out in 1993. However, the Bureau of Surveying and Mapping (BSM) at the Headquarters of General Staff (HGS) of the Peoples' Liberation Army (PLA) has drawn up a series of topography maps. These maps use a classification system that was designed for military proposes and applied for surveying the land use information in 1971 and producing a map of 1973. Because the BSM of the HGS's classification system of the PLA is different from that of the NBLA, it is essential to merge the two classifications. In 1995, the Bereau of Land Administration at Tianhe District (BLATD) drew up a land use planning map for the year of 2010.

Altitude data, designated for analysing the topographical impact on the land use, is available from the topographical maps produced by the PLA in 1973. The

topography is a relatively stable factor, as, during the last 30 years, that of the Guangzhou region is recorded as basically stable (BLATD, 1994).

Data related to socio-economic development and population changes are obtained from the statistical yearbooks published by the Bureau of Statistic of the Tianhe District (BSTD, 1984, 1985, 1986, ...1996) and the Bureau of Statistic of Guangzhou Municipality. (BSGM, 1973, 1973,....1992)

Other data sources required in this study can be seen in Table 5-1.

Table 5-1. A list of data sources

Data Types	Years	Sources	Scales	Major Information
Topographical map	1973	BSM of PLA	1:10,000	Altitude spots, control points, types of land use and classification systems, and types of administrative divisions
Current land use map	1993	BLATD	1:10,000 - :25,000	Types of land use and classification, and types of administrative divisions
Land use planning map of Tianhe District for 2010	1995	BLATD	1:25,000	Information of land use planning, report data
Land use planning map of Guangzhou Municipality	1995	BLAGP	1:10,000	Information from land use comprehensive planning, special planning
Plane photography map of Tianhe District	1992	BSMGP	1:22,000	Photographic characteristics and topographical data
Statistical data	1973-1996	BSTD BPGM		Socio-economic development, population and labour forces etc.

Notes:
BLAGP: Bureau of Land Administrative of Guangzhou Province
BLATD: Bureau of Land Administrative of Tianhe District
BSM: Bureau of Surveying and Mapping
HGS: Headquarters of General Staff
BSMGP: Bureau of Surveying and Mapping of Guangdong Province
BSTD: Bureau of Statistics in Tianhe District

5.2.1 Thematic maps

For the purpose of identifing land use change, a sequential land use map for Tianhe District over different periods must be produced. This section discusses how the required data has been obtained from the existing maps and air photographs (Table 5-1).

5.2.1.1 Topographic maps

Topographic maps were created by the BSM of the HGS in the PLA during the 1960's and published in 1973. Their co-ordinate systems were the 1954 Beijing system in which Beijing was accounted as the original co-ordinate. The altitudes of surface points were based on to the Yellow Sea Co-ordinate System (YSCS) in which the zero datum was defined as the mean sea level at the coast of Yellow Sea level in 1956. Some of the topographic maps used in this research were made by aerial surveying in 1969, investigated in 1971 and published in 1973. All of the Tianhe area is included in the 13 topographic maps both in principal maps and insets. Other maps in the study, such as the current land use map of 1993 and the land use plan of 2010, also use the co-ordinate system mentioned above.

The kilometre grids on the topographic maps were selected as the control points. In practical operation, a map of the control points was created according to the actual distribution of the kilometre grid points in Tianhe District, which was used to control the map entry. This study used 400 hundreds control point across Tianhe District. Table 5-2 presents the co-ordinates of part of the control points. The specific operation of creating the control point map can also be found in section 5.3. From the

topographic maps, altitude points and contours were used to develop the DEM (Digital Evaluation Model) (see Figure 5-2) for Tianhe District.

Table 5-2. Control points (part)

IDTI	XTIC	YTIC	IDTIC	XTIC	YTIC
1	425000,0	572000,0	11	435000,0	572000,0
2	426000,0	572000,0	12	436000,0	572000,0
3	427000,0	572000,0	13	437000,0	572000,0
4	428000,0	572000,0	14	438000,0	572000,0
5	429000,0	572000,0	15	439000,0	572000,0
6	430000,0	572000,0	16	440000,0	572000,0
7	431000,0	572000,0	17	441000,0	572000,0
8	432000,0	572000,0	18	442000,0	572000,0
9	433000,0	572000,0	19	443000,0	572000,0
10	434000,0	572000,0	20	444000,0	572000,0
...	...	...	...	...	...
...	...	...	...	...	...

5.2.1.2 Land use map

The 1973 land use map for Tianhe Distirct is based on the 1973 1:10,000 scale topographic maps (Table 5-1). Obviously, the land use types on the 1973 topographic maps have to be reclassified into the 9 main classes of land use adopted in this research (Table 5-4).

The different stages of classifying and capturing the land information in 1973 are as follows:

Firstly, the administrative boundary in 1993 was traced on the 1973 topographic map. Secondly, the boundaries of different land use types were marked. Thirdly, the various linear items, for example, the width of the highways and railways were identified.

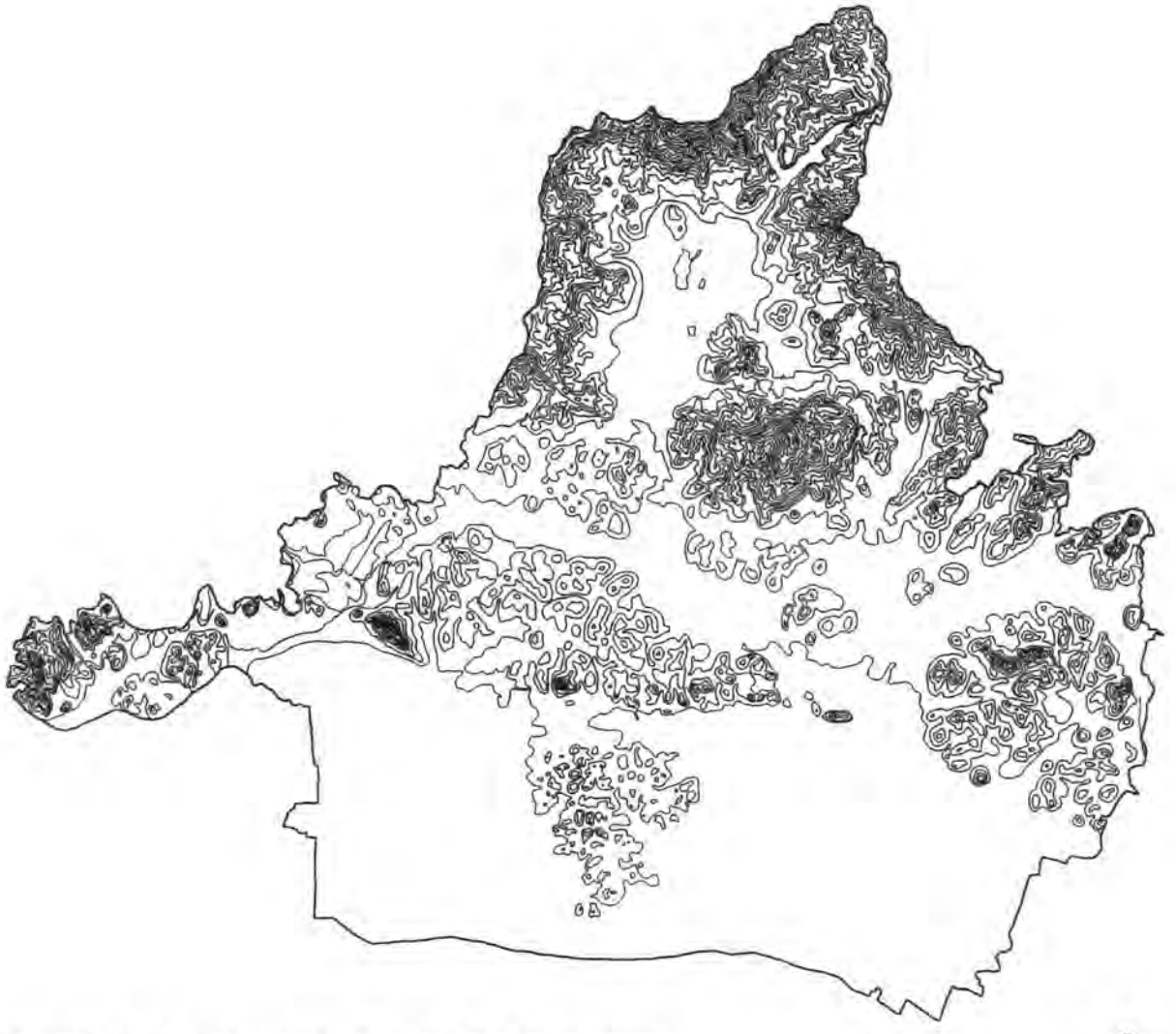


Figure 5-2. Contour map in Tianhe District, captured from 1: 10,000 scale topograpgical maps published by the Bureau of Survey and Mapping of PLA

The geomorphological information was also captured from the topographic map. The contours of 2m intervals for mountain areas and 1 m intervals for the plain were adapted on these maps. In this research, the contours are utilised at the interval of 10 metres and altitude points are chosen as 3-5 spots in a kilometre grid to shorten the time spent on digitising. The contours selected for this research are shown in Figure 5-2. These contours were used to create the DEM.

The 1993 land use map of Tianhe District was completed by BLATD in 1993. It was based on the Technical Regulation of Land Use Surveying (National Agriculture Division Commission, NADC, 1988), the Supplement Regulation of Current Land Use Investigation in Guangdong Province (SRCUIGP) (BLAGP, 1992) and other related technical documents. This surveying was based on the 1: 10,000 scale aerial photograph taken in 1987, the topographic map of the BSM of HGS of the PLA in 1973 and field checking in 1992. The first draft was completed in 1992, following by the production of the 1:10,000 and 1:25,000 scales of current land use maps with the administrative boundary depicted was completed. At the same time, the statistics and area measurement on the maps were also completed.

In this research, some related information has been obtained from the 1993 1:10,000 land use map mentioned above. The land investigation in Tianhe District was based on the National Classification System (see Table 5-3). These classes are merged into 9 land use classes adopted in this research (Table 5-3) in order to make the two datasets (1973 and 1993 land use map) comparable.

The 2010 land use map follows the recent land use plan that was drawn up for implementation in the year for 1995 to 2010

According to the Land Regulation Act (LRA) of the People's Republic of China (PRC) and the Regulation of County Land Use Comprehensive Planning (RCLUCP) of the National Bureau of Land Administrative, the BLAT carried out the land use planning map into the next century, which is guided by the principle of protecting arable land and rational land utilisation. Its planning goals were to meet the expansion of the central city of Guangzhou and the urbanisation of neighbouring cities in the region, based on the characteristics of the rural-urban fringe and rural-urban integration. It also aimed to co-ordinate and unify economic, social and ecological benefits. In this planning, the year of 1993 was determined as the baseline year and the year of 2010 as the target year. After predictions of population change and different land use requirements, the land use structure was adjusted and some planning goals for rational land use were also obtained.

5.2.1.3 Administration boundary

Tianhe District was founded in 1984 and re-organised from the former Suburb District of Guangzhou Municipality. It is difficult, therefore, to distinguish the corresponding administrative boundary from the topographic map in 1973. As discussed above, the administrative boundary in 1993 is applied mechanically to the map in 1973, hence a comparison of maps in different years can be made.

5.2.2 Statistical data

Tianhe District Statistical Yearbooks 1984, 1985, 1986 .... 1996 (BSTD, 1984, 1985, 1986..... 1996) provide information about urban growth and social-economic changes at district, town and village level. The yearbooks provide tabular information concerning the major field of social-economic changes. The data categories comprise the following series:

a) Agriculture; agricultural input (labour, investment, land, fertiliser, seed, infrastructure, etc.); agriculture out-put (crop yield, cattle, wood, fruit etc.)

b) Industrial input-output data, employment, enterprise type, products etc.

c) Other data, such as population and its structure, commerce, service etc.

The detailed data used in this research is shown in Appendix 5-1.

5.2.3 The comparison of different land use classification

Land use classification varies in accordance with the purpose of study and local situations. The land use classification system of this research was developed on the following two guidelines: first, it must be generalised to cover the classification systems of different years; second, it should meet data requirements for the trend analysis of land use changes in Tianhe District. The maps of 1973 and 1993 are based on different land use classification systems and both of them have three sub-categories. For the purpose of analysing the trends of the land use changes in Tianhe District, which is the main objective of this thesis, this research has designed a common classification system of eight categories based on both map information of 1973 and 1993, and on the indicators used by the Tianhe Land Use Planning for 2010. In this common

classification system, some sub-classes are merged to provide as near to a standard group as possible. Notably, however, the urban land, rural residential sites and industrial land are listed as three separate sub-classifications, as these types of land changed dramatically in location in Tianhe District over the study period.

The eight classes then are arable land, orchard land, wood, urban residential land, rural residential land, industrial land, water bodies and un-used land. The design of this land use classification scheme follows the principles of easy identification and adaptation to the local situation. A comparison of this classification with the others can be seen in Table 5-3.

In practice, arable land in this research includes the first and second levels of the arable land classes in 1973, 1993 and 2010. Orchard land includes the first and second levels of the orchard land class in 1973, 1993 and 2010. Woodland includes the first and second levels of the woodland classes in 1973, 1993 and 2010. Urban land includes the urban residential under the type of residential land in 1973, urban and town under the type of residential and industrial land in 1993, and urban land under the type of residential land in 2010. Rural residential sites include rural residential under the type of residential and industrial land in 1973, rural residential under the type of residential and industrial land in 1993, and rural land of residential sub-classification in 2010. Industrial land includes all of the second sub-classification of industrial land in 1973, industrial and special land under the type of residential and industrial land in 1993 and 2010. Transport land is designated for highways, railways, ports and their facilities, including the transport network in 1973, and transport land of 1993 and 2010.

Table 5-3. Land use classification schemes

1973	1993	2010	This Research
10. Arable land	**10. Arable land**	**10. Arable land**	**10. Arable land**
11 Irrigation water field	11 Irrigation water field	11 Arable Land	
12 WangTian field	12 WangTian field	12 Vegetable	**20. Orchard**
13 Water field	13 Water field		
14 Dry field	14 Dry field	**20. Orchard**	**30. Woodland**
15 Vegetable field	15 Vegetable field		
		30. Woodland	**51. Urban area**
20. Orchard	**20. Orchard**		
21 Apple	21 Fruit garden	**50 Residential and industrial land**	**52 Rural residential**
22 Banana	22 Mulberry		**53 Industrial**
23 Other fruit		51 Urban	
	30. Woodland	52 Rural	**60. Transport land**
30. Residential land	31 Mature woods	53 Industry	
31 Urban residential	32 Bush woods	54 Special	**70. Water body**
32 Rural residential	33 Sparse woods		
	34 Afforestation		**80. Unused land**
40. Industrial land	35 Nursery	**60. Transport**	
41 Heavy industry		61 Railway	
42 General industry	**50. Residential and industries land**	62 Highway	
43 Military	51 Urban and Town	63 Village road	
	52 Rural residential	64 port	
50. Transport network	53 Industries		
51 Single-track railway	54 Special Land	**70. Water**	
52 Double-track railway		71 River	
53 Electrified railway	**60. Transport land**	72 Reservoir	
54 Narrowgange railway	61 Railways	73 Pool	
55 Building railway	62 Highways	74 River Coast	
56 High speed road	63 Rural roads	75 Hydropower	
	64 Civil airport		
60. Water body	65 Port and yard		
61 Canal			
62 Lake	**70. Water body**		
63 Reservoir	71 River surface		
64 Pool	72 Lake surface		
	73 Reservoir surface		
70. Wood and grass land	74 Pool surface		
71 Forest	75 Reed		
72 Young woods	76 Beach		
73 Nursery woods	77 Irrigation canals		
74 Economic wood			
75 Protecting woods	**80. Unused land**		
76 Bamboo woods	81 uncultivated land		
77 Bush woods	82 Saline and alkali		
78 Grass lands	83 Swamp		
	84 Sand		
	85 Gravel		
	87 Field ridge		
	88 Other		

Water body and unused land in this research correspond to those of sub-classes in 1973, 1993 and 2010.

Before the data collection was undertaken, all of the original maps in the three years are firstly merged based on the classification system mentioned above, and then digitised. It can be seen from Figure 6-1, Figure 6-3 and Figure 6-5 that three digitised maps in the three years are created using the same classification. Therefore, these three land use maps are comparable since they now are based on the same class scheme.

The land use planning map shows more general characteristics of land use than that of 1973 and 1993 and its functional districts are more well classified. Practically, the planning maps of 2010 are developed for the local government to control the use of land. This planning is currently being implemented. With respect to this fact, as has been discussed in the introduction and Chapter 7 of this thesis, it should be acknowledged that this planning represents the land use pattern of Tianhe in 2000, even though the land use in 2010 might not be exactly as planned. On the whole, the maps based on the comprehensive classification of this research can be compared if it is used for the analysis on the comprehensive change trends of land use in the three development stages of Tianhe District.

5.3 Database development

Dveloping the spatial information database is the key step to spatial analysis. This section mainly discusses the basic steps and methods for the development of the

spatial information database in this research. First, reasons are discussed for the application of the GIS software. Second, the necessity of a coding system is given. Finally, the entry and correction of the maps, the fundamental methods and steps of the contribution data are also presented.

5.3.1 GIS and Arc/Info

Arc/Info, the production of Environment Systems Research Institute (ESRI) is used in this research. It has been one of the most popular GIS software since the first release in 1982. It has been constantly improved and updated over the years. It enables users to harness the power of GIS analysis and data management as never before. It integrates an entire line of GIS solution software. It contains a hybrid GIS design of ARC, a graphics package linked to INFO, and a related DBMS. It runs on workstations using UNIX and VMS operating systems as well as on personal computers. It provides practically all of the functions needed for the current study.

5.3.2 Coding system

Defining a coding system is the primary step of data entry. It plays a key role in controlling the map entry, linking and joining maps and databases and other data handling. The coding system in this research includes three parts, the control point coding system, contour coding system, and land use coding system.

A) The control point coding system

The control point system is used to control the map entry and to merge the maps. It guarantees the precision of the map entry. Because all of the maps used in

this research were adopted from the Beijing co-ordinate system, and there are kilometre grids on the maps, the cross points of the kilometre grids are selected as the control points. The design principles are given as follows: 1) The control points can control all of the map entry; 2) The control points are arranged in order;

The stages in arranging control points are as follows;

1) Determine the scope of the area and mark the outline of the control point

2) Determine the co-ordinates of the far upper-left control point and far down-right, to ensure the input of all maps in the control area;

3) Place the first control point at the upper-left corner and subsequent control points from left to right in order, through to the end of the same row, with the second row arranged in the same way down to the right-hand corner.

B) The contour coding system

The attributes of the contours and altitude point are defined as the value field itself. Since the altitude points are inputted in the point mode, the co-ordinate values of the altitude points are rounded so as to simplify the entry process of the altitude point.

C) The land use coding system

The subject attributes include two aspects: surface attribute and linear attribute. The former includes arable ,orchard, wood, and grass land etc.; whilst the latter are found in the linear features, such as highways, railways, boundaries and administrative boundaries, etc. The details of land use coding system are listed in Table 5-4.

Table 5-4. Land use coding systems list

Land Use Types	Code	Linear Subject Types	Code
Arable land	10	Railway	61
Orchard	20	Highway	62
Wood	30	Rural road	63
Rural residential	52	Sewage	77
Urban area	51	Land use type boundary	101
Industrial	53	Village boundary	301
Transport	60	Town boundary	302
Water body	70	County boundary	303
Un-used land	80		

5.3.3 Digitisation and coverage preparation

In this study, data entry comprises both map digitising and input of related attribute data The former includes the preparation of control points, entries of the land use plot form land use maps in three different years, and entry of the contours. The latter includes entries of the width of the linear features and the socio-economic data related to the land use parcels.

5.3.4 The modification and emergence of the maps

The stages of modification and emergence of the maps are:

1). To build up the spatial topology of arcs, points, and polygons.

2). To delete the suspended arcs, join the arcs, add the losing lines, modify the deformed lines and wrong attributes and add the losing attribute points;

3). After the maps in the same year are examined and proved correct, they are merged for further analysis, becoming the contour maps, and land use maps in the three different years. These maps, are called the mother maps and will be used in the further data handling.

5.4 Data analysis

After the development of the spatial framework it is necessary to take a series of operations so as to provide useful data for spatial analysis in chapter 6.

Data manipulations at this stage mainly include the extraction of the thematic maps, the development of DEM, slope measurement, and area zoning calculations.

5.4.1 Extraction of thematic maps

After a series of data manipulations, thematic maps can be derived from the mother maps. The single factor maps can be attained for comparative analysis. For example, transport lines extracted from different maps can reveal the trends of transport change in the area. The urban land use maps, on the other hand, can show the expansion of urban land use in both the past and future.

5.4.2 The DEM and slope measurement

In order to analyse the role of the topographic factor in the transformation of the land use types, it is necessary to measure the slope by extracting the contours and altitude points. This process involves the use of a GIS package. In Arc/Info Version 7

(ESRI, 1994), the TIN (Triangulated Irregular Network) and GRID provide the functionality.

In the frame of TIN in Arc/Info, the CREATETIN command uses a linear relationship between the sampling points, establishing a surface based on a triangulated irregular network. By CREATIN, the regions with constant value or without data can be specified. Created using contour lines and height points, the tin is converted it into DEM. The TIN model stores the topographical relationship between triangles and their adjacent neighbours. This data structure allows for the efficient generation of surface models for the analysis and display of terrain and other surface types.

By using GIS functionality, a slope map is created. However it is necessary to classify the slope before the slope map can be used. According to the classification regulation of the National Current Land Use Survey (NADC, 1981), the slopes can be divided into the four classes, $0\text{-}2^0$, $2\text{-}6^0$, $6\text{-}15^0$ and above 15^0. This classification is based on the influence of the slope on agricultural production. Surface area with the slope of $0\text{-}2^0$ is plain land suitable mainly for mechanical cultivation and water irrigation. The area with the slope of $2\text{-}6^0$ is partly arable land that is convenient for mechanical cultivation and water irrigation. These areas are also suitable for the development of economic crops and fruit plantations with good topographical conditions and light land erosion. The areas with the slope of $6\text{-}15^0$ need to be reclaimed but bad performance can easily cause soil erosion. These areas are suitable for orchard plantation and partly for crop plantation. The areas with greater than 15^0 are difficult to reclaim and can be

developed for woodland. Areas with a slope of greater than 25° must be prohibited to breed in order to allow afforestation.

Table 5-5. The classification of slope

Grade	Slope	Classification principle
1	0-2°	plain land, mechanical cultivation and good irrigation
2	2-6°	suitable for mechanical cultivation and well water irrigation
3	6-15°	to be reclaimed but bad performance can easily cause soil erosion; suitable for orchard plantation and partly for crop plantation.
4	>15°	generally unsuitable for agricultural use but suitable for plantation of orchard and forest;

5.4.3 Area zoning and calculation

For the purpose of the analysis of land use variation with time and space and the relationship between land use structure and slopes, one needs to undertake some spatial operations in order to obtain the necessary information.

1: The creation of buffer zone map

Taking the Haizhu Square in central Guangzhou as a co-ordinate, a fan-shape zonal map is created with 1 km interval. It can be seen from Figure 5-3 that the land distribution of Tianhe district falls between the scope of 13 kilometres and 30 kilometres from the city centre, most of them in fact from 18 to 27 kilometres.

2: Overlay

This zonal map is overlaid onto land use maps of different years, to obtain the land use structures among different kilometre belts in various years. According to these maps, the differences of land use structures on space can be sketched out.

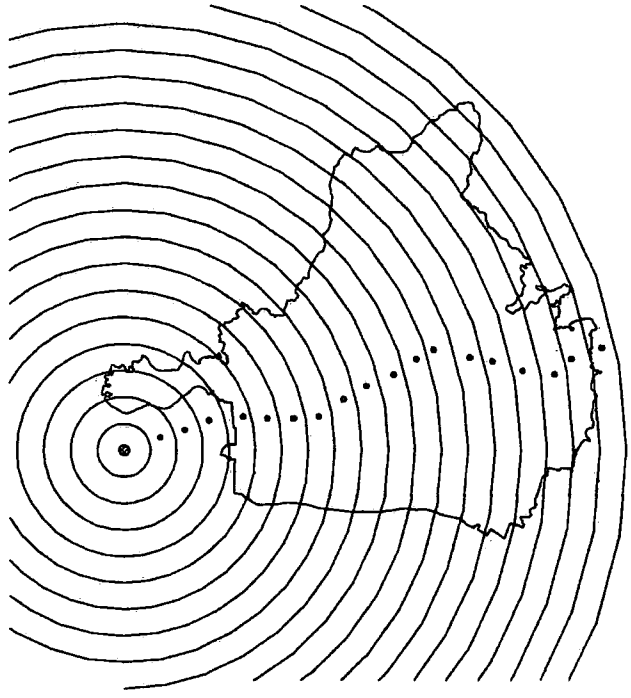


Figure 5-3. The zonal map for Tianhe District

Using the same handling methods, the slope maps created in the last section are overlaid upon the buffer zone map. The variant principles of slopes on space can also be concluded from the statistical analysis.

Furthermore, the slope maps are overlaid with the land use maps to establish the relationship between the land use and slopes. The overlay among the slopes, land use maps and the buffer zone map can create the interrelationship between them.

3. Area calculation

Throughout the steps mentioned above, different kinds of areas are accounted and measured to provide tables and charts. The database and related software in the Arc/Info package can provide the statistical tools.

5.5 Summary and conclusion

The fundamental function of the GIS is to link the different kinds of spatial and attribute information, and to store these information into a digitising format provides the opportunities for comprehensive spatial analysis. In this chapter, the data sources and data entry has been discussed in detail. We have also presented the ways in which the information of land use are captured, classified and accounted. During the preparation of the spatial database, it is important to consider the models of the subsequent spatial analyses. In this way, the database can be prepared to suit our needs. Also important is that some intermediate maps such as the zonal map need to be created at this stage for the analysis to come later.

CHAPTER 6

LAND USE CHANGES OVER TIME AND SPACE

6.1 Introduction

The structure and distribution of land use in a region are normally associated with economic development, population growth, change in industrial structure and national policies and laws in various periods. Based on analysis of historical data, the evolution of land use structure and distribution of the region can be established, hence allowing prediction on their trends. According to this assumption, this chapter analyses the following three aspects of land use change in Tianhe District. Firstly, the land use situations in different years are discussed to reveal their fundamental characteristics in the three years (1973,1993 and 2010), and to yield overall trends of land use change on a comparative basis. Secondly, the spatial differences of land use are characterised according to distance from the city centre. Finally, the main emphasis is put upon the impacts of slope on land use distribution.

6.2 Land use analysis over time

In this section, the patterns of land use change in Tianhe District in 1973, 1993 and 2010 are discussed, based on the analysis of land use structures in these years. It

aims to cover the general patterns in the change of land use structure in the process of urbanisation in Tianhe District.

6.2.1 Changes in land use structure over time

From analysing the land use structure of Tianhe in 1973, it is apparent that the District was characterised by its agricultural nature, as indicated in Figure 6-1. Most of the area of Tianhe District was arable, orchard and woodlands, which accounted for 80.2 % of the total land area (Figure 6-2). The total area of residential and industrial lands (including urban, industrial and rural residential lands), accounted for only 12.8 %. Among these land use types, rural residential land occupied nearly 4.9% of the total area, whilst industrial land occupied 7.3%. Urban land use was only 0.6% of the total land area. Most of the urban land fell into the area of Shahe Town. Consequently, from the view point of urban development, Tianhe District in 1973 lacked any so-called urban land use.

Over the past two decades, as a result of urban expansion in Guangzhou, a great change has taken place in Tianhe District. As indicated in Figure 6-3 and Figure 6-4, the most apparent change was that urban land use expanded southeastward along the railway line. In 1993, urban residential land use area in Tianhe District accounted for 15.7% of its total land area. With industrial and rural residential land added, the subtotal reached nearly 40 %. Apart from the northern hilly areas, factories and enterprises were distributed in every corner of Tianhe District. The arable land decreased sharply, from 1973 to 1993, for example, from 37.2 % to 16.5 %. Moreover, it was compressed into several strip-like belts. As a fact of matter, when

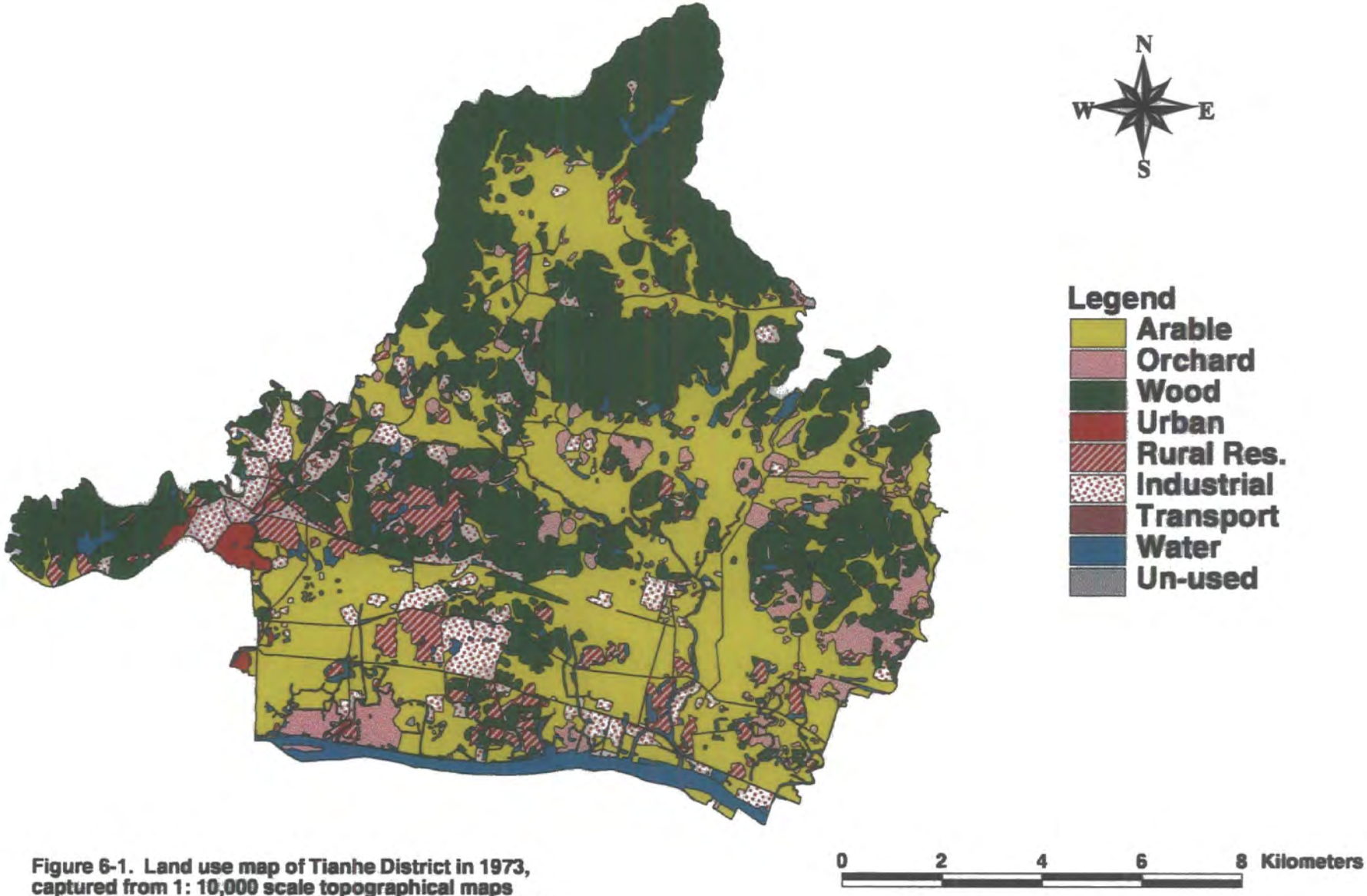


Figure 6-1. Land use map of Tianhe District in 1973, captured from 1: 10,000 scale topographical maps published by the Bureau of Survey and Mapping of PLA

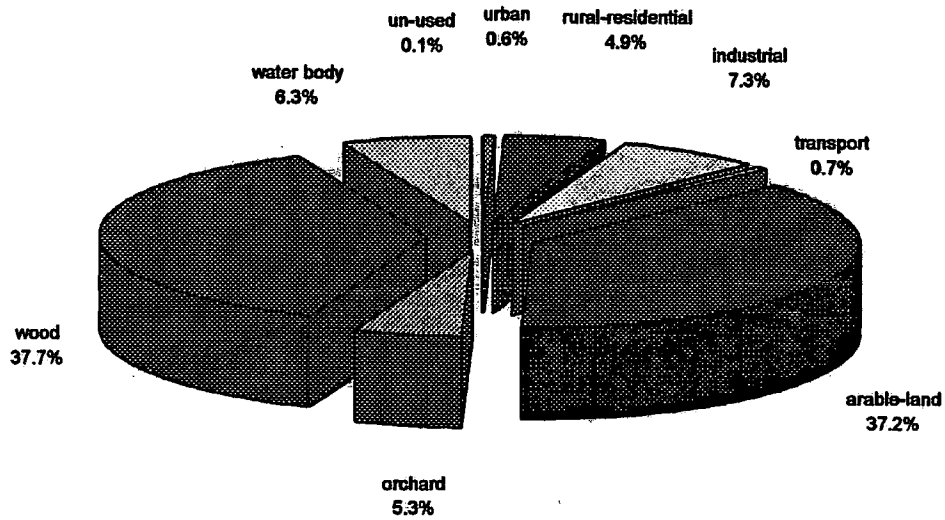


Figure 6-2. Land use structure in 1973

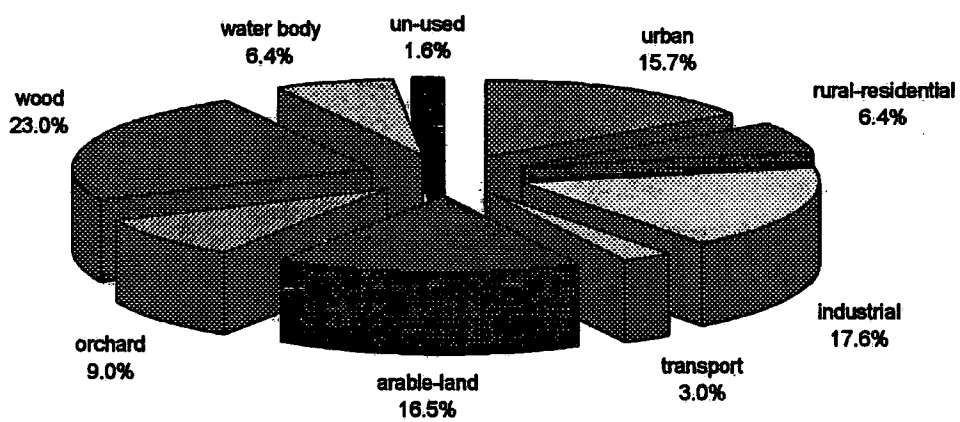


Figure 6-3. Land use structure in 1993

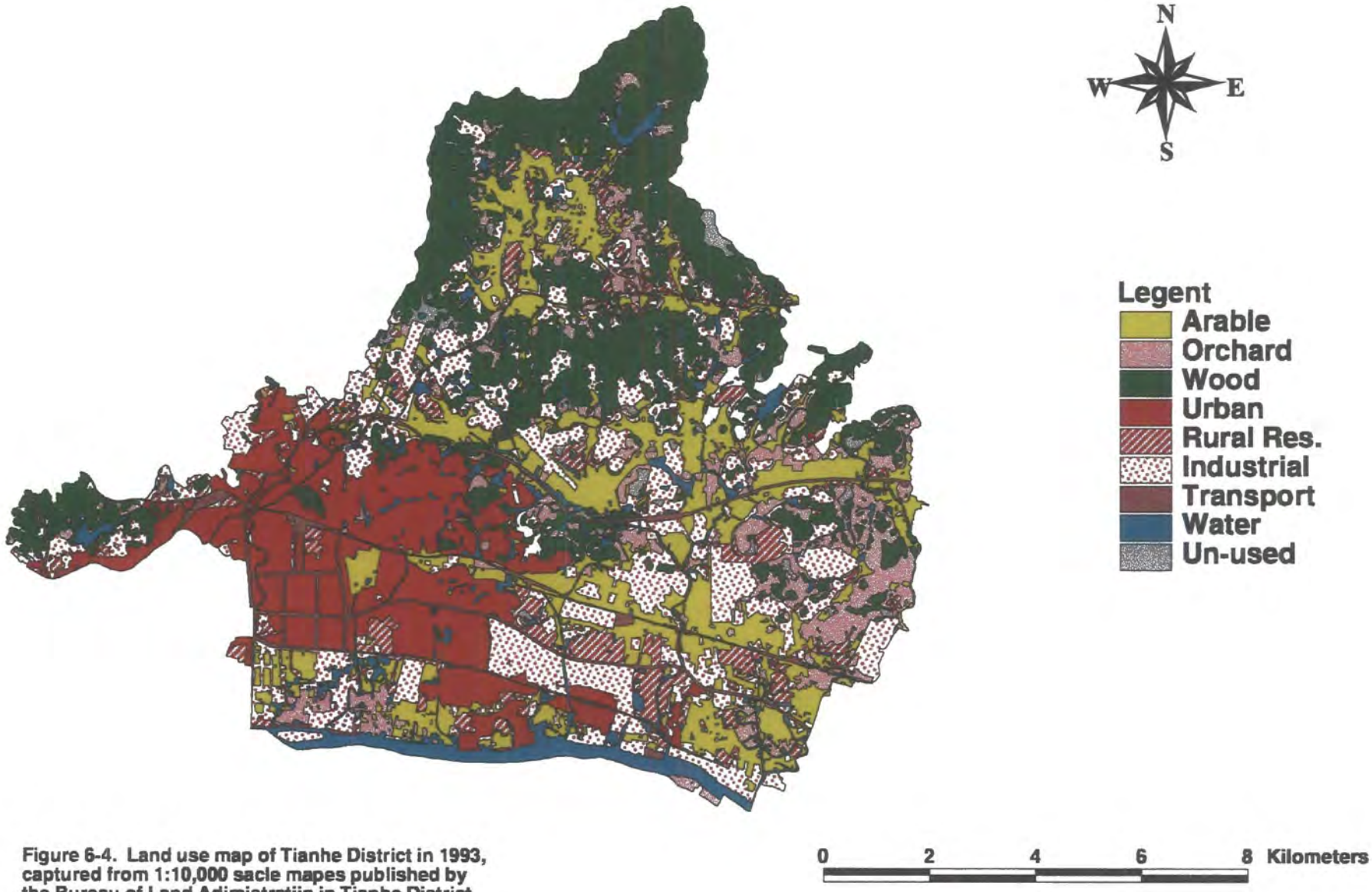


Figure 6-4. Land use map of Tianhe District in 1993, captured from 1:10,000 sacle mapes published by the Bureau of Land Adimistratiin in Tianhe District

the author undertook a field reconnaissance in 1997, two scattered areas of arable land in the southwest region were lost as a result of the development of the New Pearl River Technology City (NPRT).

As for the woodland, its share of the total area fell from 37.2 % to 23.0 % while orchard land increased slightly from 5.3 % in 1973 to 9.5 % in 1993. In addition, transport land increased from 0.7 % to 3.0 % in the same period. The whole land use structure exhibits development characteristics in a comprehensive way.

Land use plan in Tianhe District for 2010 shows another pattern of land use structure (Figure 6-5, Figure 6-6). The subtotal area of urban and industrial land is expected to increase to 73.3 %. It can be seen in Figure 6-6 that the southern part of the District, except for a few green spots, will be fully developed into urban and industrial land use. With the urban expansion, most of the rural residential site will be merged into urban regions. Whilst the arable land will decrease to only 0.5 %, woodland will shrink back to the ring-shape belts in northern part of the District,

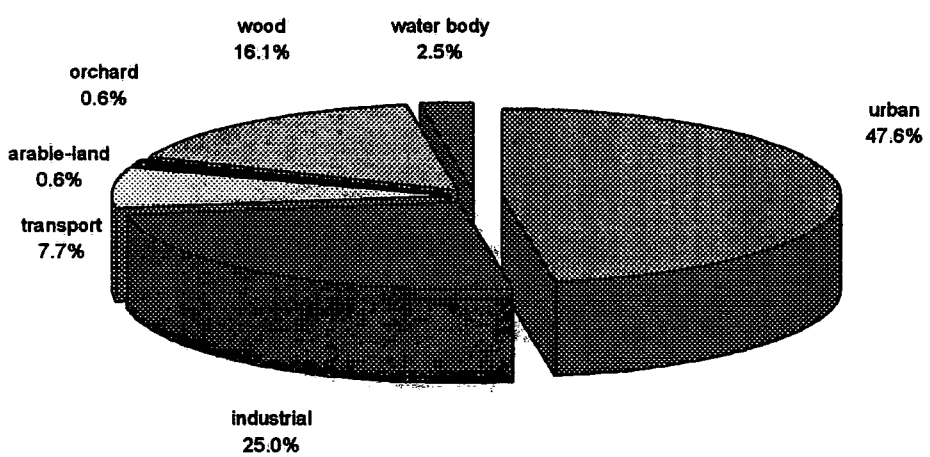


Figure 6-5. Land use structure of the land use plan for 2010

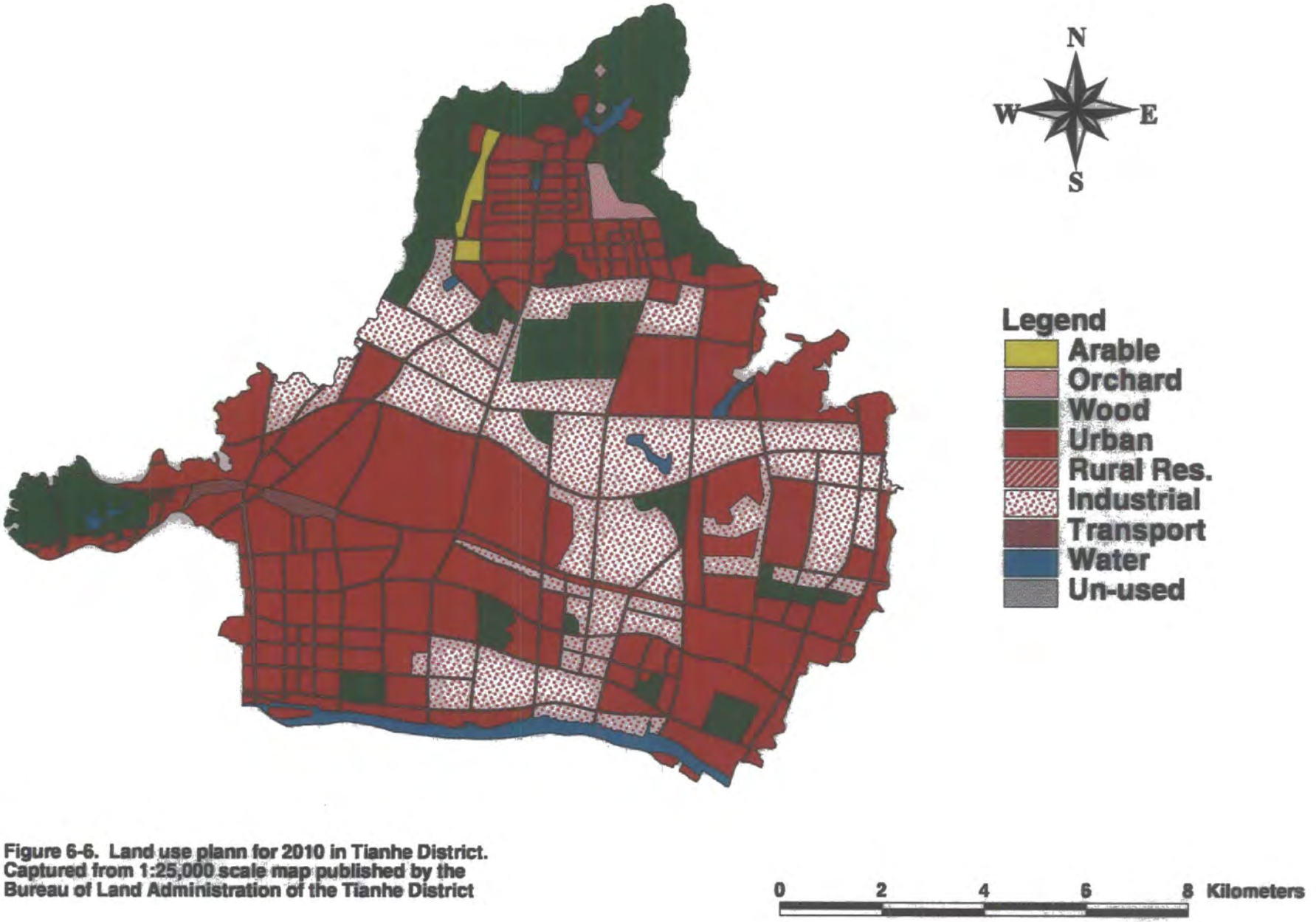
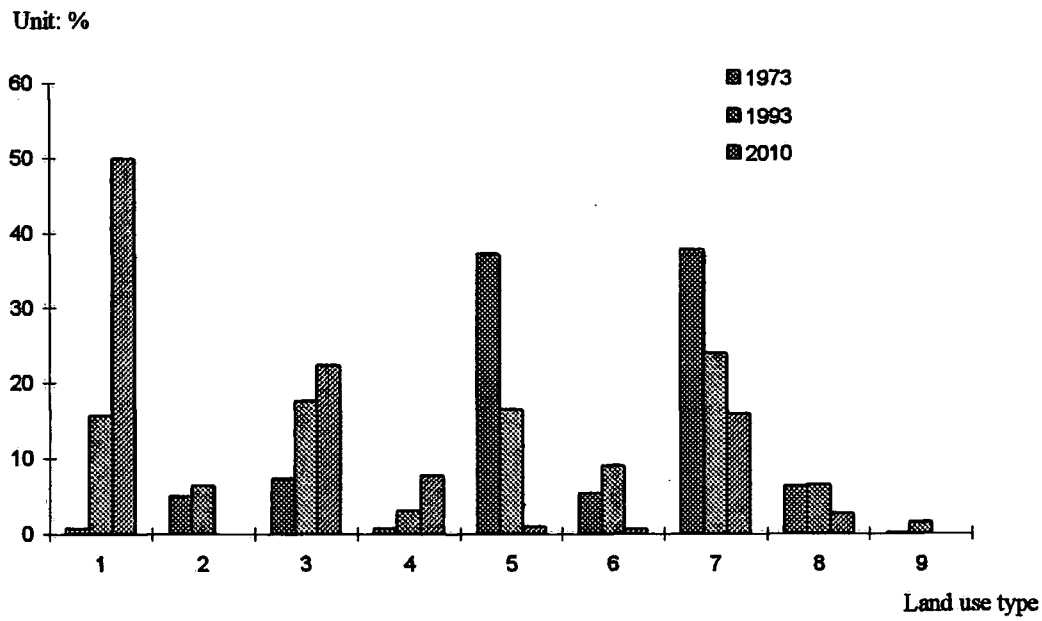


Figure 6-6. Land use plann for 2010 in Tianhe District. Captured from 1:25,000 scale map published by the Bureau of Land Administration of the Tianhe District

and a few will be scattered sparsely around Shahe Town. Water bodies, unused land and orchard lands will also decrease sharply, to 1.3 %, 0.0 % and 0.6 %, respectively. Transport land will exhibit an increase trend, from 3.0 % in 1993 to 7.7 % in the year of 2010. Tianhe District will show a homogeneous urban land- use pattern by 2010.

6.2.2 Trends in the land use structure

Comparing the land use situations in various years, it can be seen that the land use structure possesses the following characteristics that are summarised in Figure 6-7, which is after Figure 6-2, 6-3 and 6-5.



1	urban	6	orchard
2	rural residential	7	wood
3	industrial	8	water body
4	transport	9	unused land
5	arable land		

Figure 6-7. Trends of land use structure in different years
Data are from Figures 6-2, 6-3 and 6-5.

Firstly, shown in Figure 6-7, urban, industrial and transport lands have been increasing, with an increasing share of urban land use. Urban land increases from 0.6% in 1973 to 15.7% in 1993, and 50.06% in 2010. Industrial land expanded from 7.3% in 1973 to 17.6% in 1993, and 22.3% in 2010, whilst the share of transport land was raised from 0.7% in 1973 to 3.0% in 1993 and 7.7% in 2010.

Secondly, arable land and rural land show sharply decreasing trends. In terms of shares of the land use structure, arable land share decreased from 37.2 % in 1973 to 16.5 % in 1993 and 0.9 % in 2010 (Figure 6-7). Over the same periods, woodland shares are 37.7 %, 24.0 % and 15.9 %; the water body changes similarly.

Thirdly, rural residential and orchard lands slowly increased at first and then fell sharply. The share of rural residential sites increased from 4.9 % in 1973 to 6.4 % in 1993 but in 2010 they are merged into the urban land use category. The orchard land share increased from 5.3 % in 1973 to 9.0 % in 1993, but it will fall down to 0.6 % in the year 2010. The water body share in 1993 was similar to that of 1973 but will decrease to 2.6 % in 2010 which includes part of Pearl river in Tianhe District.

Fourthly, the unused land area shows a special apparent change in character. Its share in the land use structure is 0.1 % in 1973, 1.6 % in 1993 and 0.0 % in 2010. These data mis-represent the actual situation. Because the unused land in Tianhe District in 1973 exhibits a sparse scattered pattern along the both sides of rivers, most of the wasteland was included in other types of land. Another reason derives from the difference of the classification systems. In the land survey of 1993, the unused land was included the wasteland, field ridge land, etc.; but in the land classification in 1973, the field ridge land was not regarded as a sole category and was included in the arable land. Moreover, it was difficult to distinguish parts of wasteland from the

grassland; thus both were included in the class of grassland. In this research, grassland is included in the woodland class.

In summary, based on above analysis, it is seen that Tianhe District has changed from a rural suburb 25 years ago to a rural-urban fringe in 1993, and will finally be urbanised in 2010.

6.3 Land use change in space

The spatial distribution of land use in Tianhe District is discussed in this section. Firstly, it focuses on the analysis of the changes in land use structures in the three surveys according to the distances from Guangzhou City centre. Secondly, a general spatial change of land use will be analysed over time, with emphasis on change of land utilisation by urban, industrial, arable, woodland development.

6.3.1 Land use change on the distance axis

Land use variations with the distance from the city centre in 1973 is shown in Figure 6-8, whilst the land use structures in each kilometre belt are illustrated in Figure 6-9. In the range of 2-4 kilometres, wood, water and rural residential land uses account for the greatest share of the land use structure. This strip is located in the southern part of Shahe Town, dominated by hills. From the city centre to further distances, woodland use increases gradually and its share of the total land use reaches to 50 % as a result of the topographical effect (see discussions in Section 6.4). From the 5-6 kilometre belt to the 7-9 kilometre belt, the share of wood land use increase

from 7.8 % to 24.0 % on average, and this increasing trends remain with 35.0% in the 10-15 kilometre belt and 57.6% in the 16-19 kilometre belt. Because the orchard land share of the total land use structure is only 5.3 %, its spatial distribution exhibits sparse characteristics. The share of orchard land in the 5 kilometre belt is only 0.4 %; in the 6-7 kilometre belt it accounts for 8.5 %, and rises largely up 14.7 % in the 19 kilometre belt. The share of transport is inversely proportional to the distance from the city centre, with three different sections. The average shares of transport are 2.0 % in the 2-7 kilometre belt and 0.8 % in 7-13 kilometre belt, but it falls to less than 0.5 % in the 14 kilometre belt. As for the water body, its share does change greatly in different belts. Shown in Figure 6-1, apart from the Pearl River, most of ponds are distributed in front of hill areas. The unused land share is too small to be shown in the Figure 6-1, 6-8 and 6-9, being mainly distributed in the 3-10 kilometre belt and its average share is only 0.3 %.

Urban land use concentrates in the 4-5 kilometre belt, wherein lies the centre of Shahe Town (Figure 6-1). The distribution of rural residential land use mainly concentrates in the second kilometre belt with the maximum share of 29.3. The shares decrease from the onset of the 6-11 kilometre belts with a share of 11.2 % to that of 2.5 % in the 12-19 kilometre belts.

The land use distributions of industrial land possess a similar pattern to that of rural residential sites. On average, the share of industrial land use is 18.3 % in the 5-9 kilometre belt and falls to 6.7% in the 10-13 kilometre belt, and reduces further to 2.1

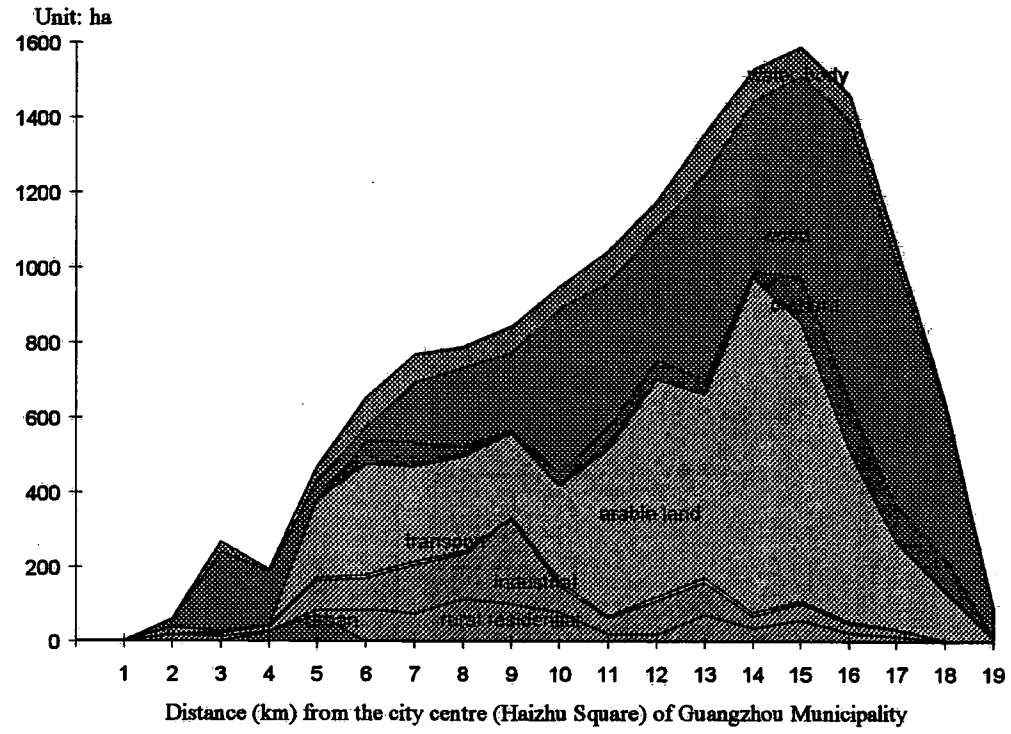


Figure 6-8. Land use type variations with distance in 1973 (value)

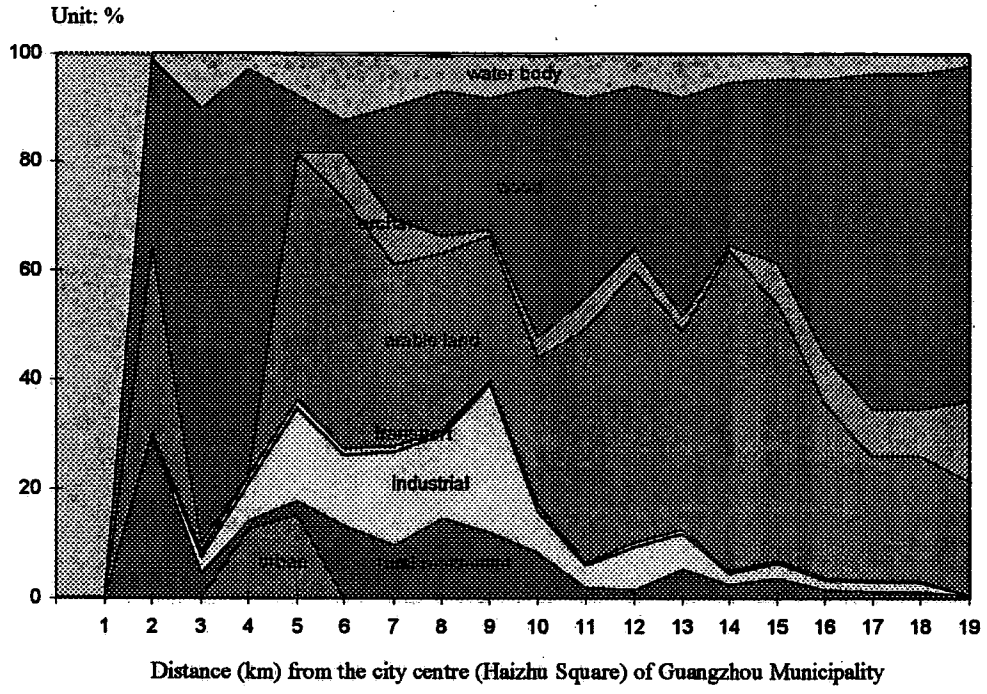


Figure 6-9. Land use structure variations with distance in 1973 (percentage)

% in the 13-17 kilometre belt but disappears at 18-19 kilometre belt. The shares of arable land use range between 40 % and 50 % in most of kilometre belts except for the 4 kilometre one. In terms of average shares of arable land use in all kilometre belts, four areas can be divided, that is, the share is 45.5 % in the 5-6 kilometre belt, 29.7 % in the 7-10 kilometre belt, 47.3 % in the 11-15 kilometre belt, and 26.1 % in the 16-19 kilometre belt.

With respect to the situation in 1993, the most apparent characteristics can be seen in Figure 6-10 and Figure 6-11. Firstly, the urban land use clearly expanded outwards. From the view point of distribution, urban land use concentrates in the 2-10 kilometre belt where the share of urban land use accounts for 43.70.0 %, and 6.1 % in the 11-12 kilometre belt where the administrative centre of Dongpu Town is to be found. There is urban land use beyond the 13 kilometre belt. One particular case is that in the third kilometre belt exists 13.7 % of urban land use share. This is mainly because that belt is a hilly area where the topography limits the urban development.

Five kinds of industrial land distribution can be found taking all of the belts together. The maximum share with an average of 23.2 % falls in the 2-3 kilometre belt, but it decreases to 13.7 % in the 4-9 kilometre belt; in the 10-14 kilometre belt it begins to rise on average to 23.4 % but decreases to 14.4 % in the 15-17 kilometre belt, and it is only 4.2 % in the 18-19 kilometre belt.

The transport land use possesses bigger shares in the 4-7 kilometre belt than that of others. Its share reaches 11.7% in the 5 kilometre belt and 7.7 % in the 6 kilometre belt. All four belts from 4 to 7 kilometres are represented in the central area

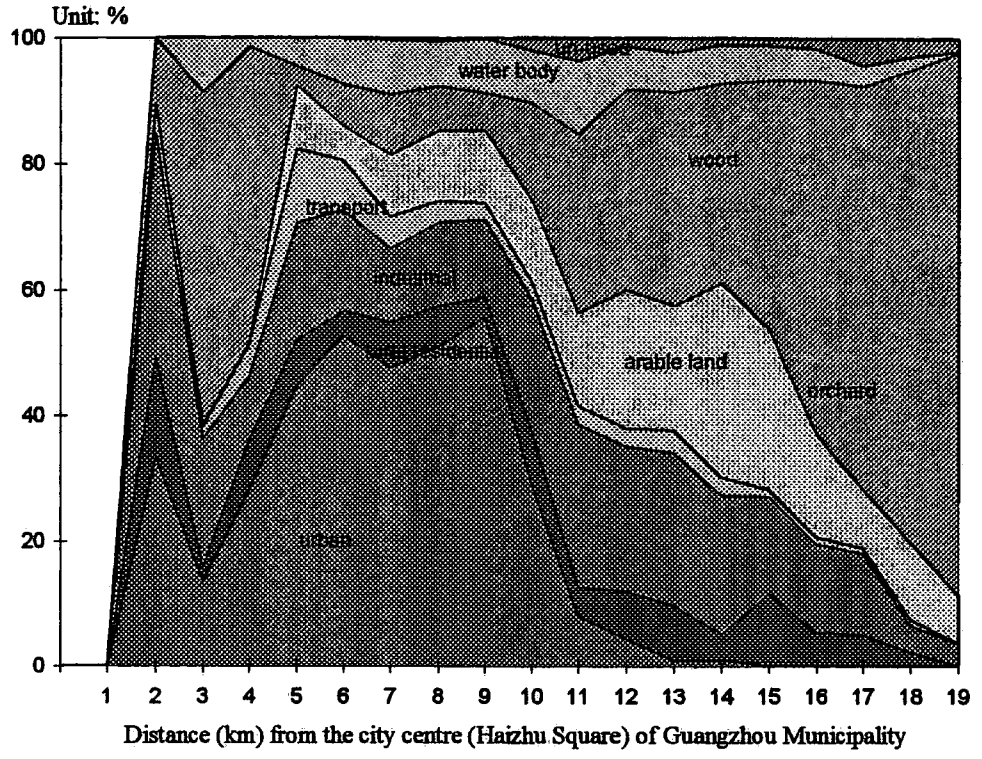


Figure 6-10. Variations of land use type by distance in 1993 (value)

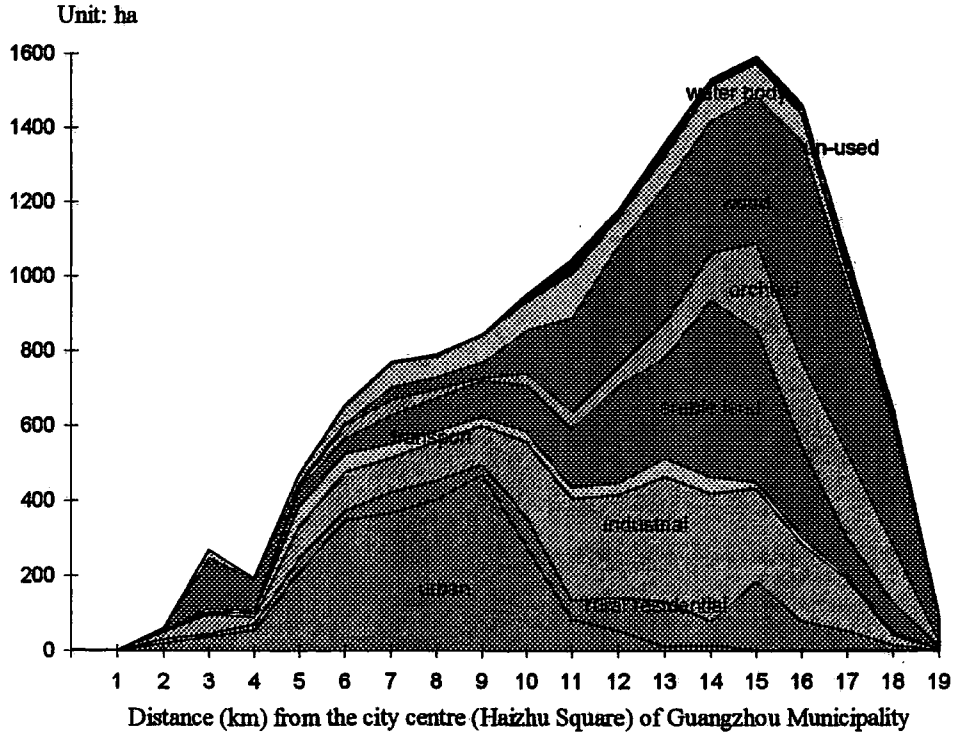


Figure 6-11. Variations of land use structure by distance in 1993 (percentage)

of Tianhe District, where the new Tianhe Gymnasium centre and the new Tianhe railway station were built. The shares of transport land use are about 3 % from 8 to 14 kilometre belts but decrease to 1.1 % in the 15 kilometre belt and zero in the 19 kilometre belt where there is no major transport prevision.

Adding all the four non-agricultural land use shares which are related to urban and residential construction, it can be seen that this subtotal accounts for 70 % in the 2-10 kilometre belt and nearly 40 % of land in the 11-17 kilometre belt.

The arable land share is almost absent in the 2-4 kilometre belt but the share of arable land increase with the distances from the city centre. In the 4-5 kilometre belt it accounts for only 7.3 %, but increases to 13.5 % in the 6-12 kilometre belt and rapidly ascends to 20.4 % in the 12-19 kilometre belt.

As a result of topographical effects, the shares of woodland use in the 3 and 4 kilometre belts account for 49.7 % and 44.7 % respectively, but on average they are only 5.1 % from the 5 to 10 kilometre belts; From the 11 to 15 kilometre belts it increases to 25.2 % and exceeds 44.2 % in the 16-19 kilometre belt. If the shares of arable land, orchard land and woodland are added together and regarded as a broad rural use, it is apparent that the farther the distance from the city centre, the larger their shares. These shares increase from 31.8 % in the 2-3-kilometre belt to 20.3 % in the 4-11 kilometre belt; then increase from 31.8 % in the 12-15 kilometre belt to 43.5 % in the 16-19 kilometre belt.

The planned land use shares for the year 2010 represent the targets of the comprehensive planning scheme (Figure 6-12, Figure 6-13) under which Tianhe District will be developed into a urban region, with urban and industrial land uses

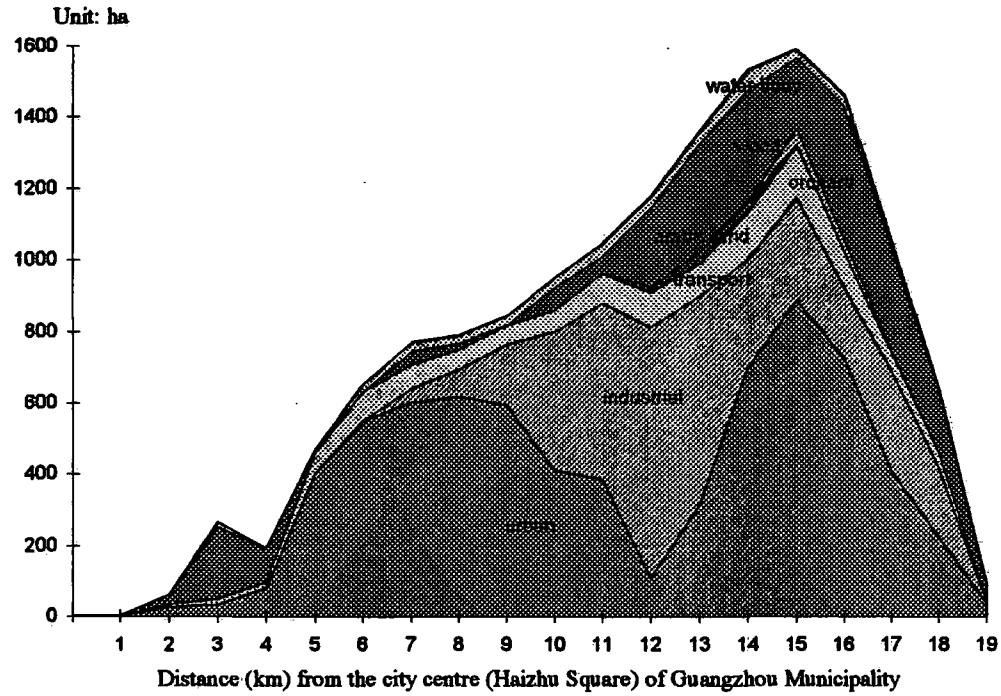


Figure 6-12. Variations of land use types by distance according to the land use plan for 2010 (value)

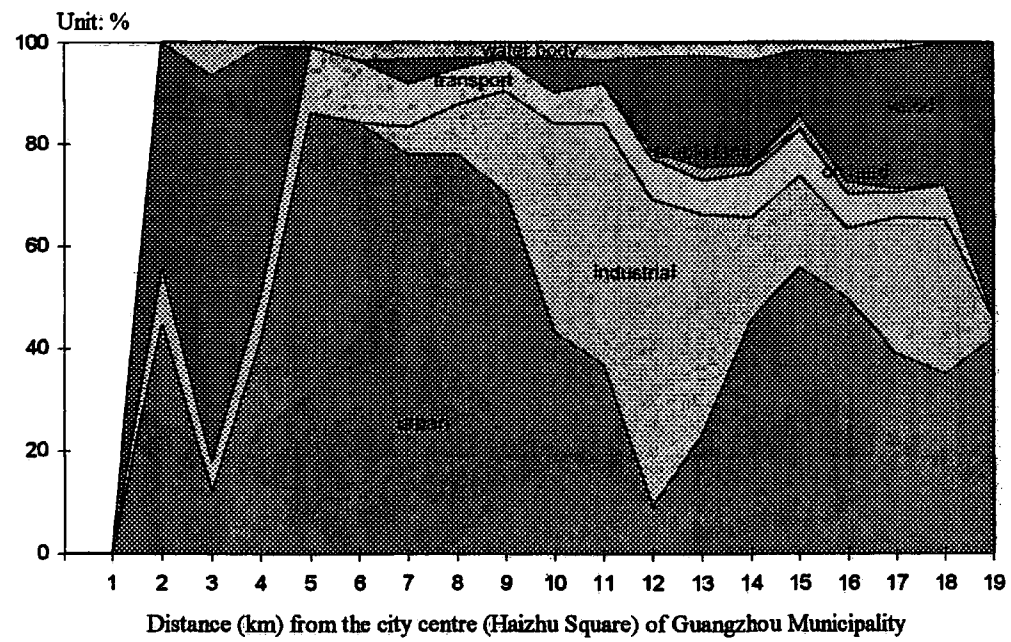


Figure 6-13: Variations of land use types by distance according to the land use plan for 2010 (percentage)

dominating its land use structure. In the 2-4 kilometre belt, these two types of land use are around 26.7 % of the total on average and increase to 38.6 % in the 5-9 kilometre belt. In the 10 to 19 kilometre belt urban land use share will account for 38.6 %, but the industrial land use share will mainly concentrate beyond the 8 kilometre belt and increase from 9.7 % in the 8 kilometre belt to 30.1 % in the 9-18 kilometre belt. If both of them (urban and industrial) are added together, the subtotal share will account for 72.6 % on average. However, the rural residential land will disappear, and most of it will be converted into urban land utilisation, which illustrates the rapid urbanisation process. The shares of transport land use will increase more and spread more evenly than before. They will on average reach 7.7 % across the region. However, the arable land use will almost disappear, with some only in the 12-14 kilometre belt. According to the Figure 6-5, two farm areas will be kept in front of the hills in north Tianhe. The shares of orchard land use appear similar to those of the arable land use. They account for about 2.6% in the 15-16 kilometre belt and will be conserved in the north of Tianhe District. The shares of woodland mainly stay in the hilly area at the 2-4 kilometre belt accounting for 62.4 %, but they will be only 3.0 % in the 5-11 kilometre belt and retain 21.5 %or more beyond the 12 kilometre belt. The water bodies in 2010 will be similar to the situation of 1993 but unused land will not exist.

6.3.2 The trend of land use change over time and space

As shown in Figure 6-14, urban land use illustrates an outward expansion trend from the city centre. Comparing urban land use shares in 1993 with those of 1973, urban land mainly expands in the 3-11 kilometre belt. Shahe Town will grow whilst Dongpu Town is expanded into a new satellite town (see Figure 6-15). Comparing the 2010 plan with the map of 1993, urban land will grow in the 3-11

kilometre belt and further in the 12-19 kilometre belt. One part is centred around the Dongpu Town whilst another is around the Tourist Vacation Village at the north of the Longdong village.

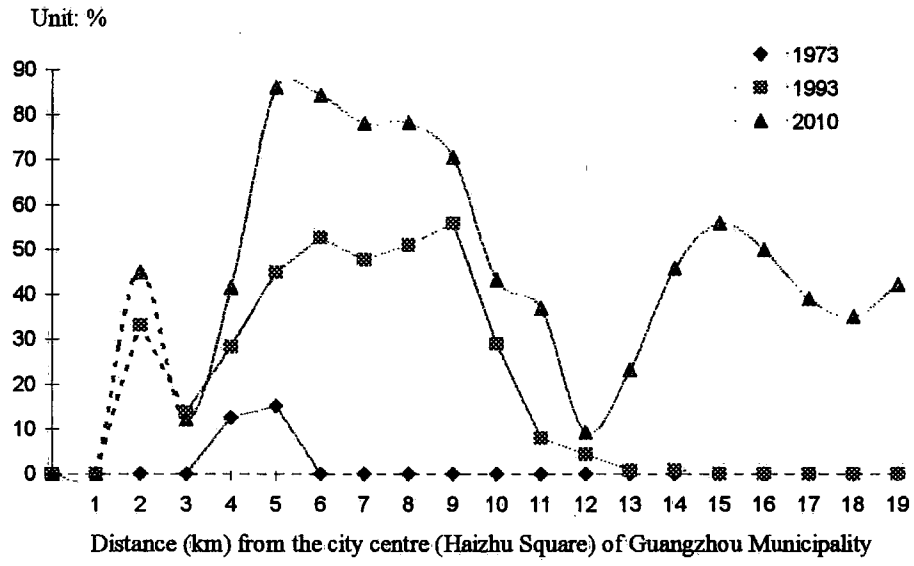
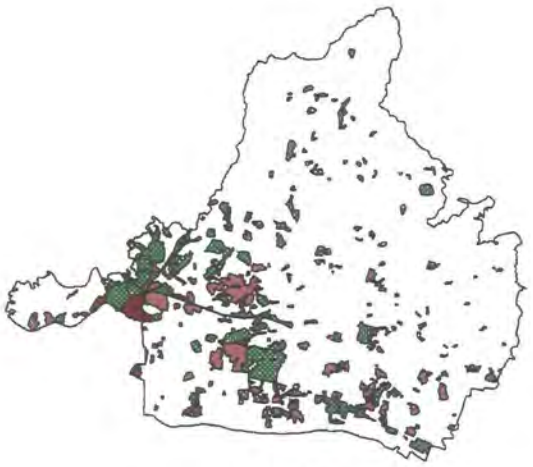
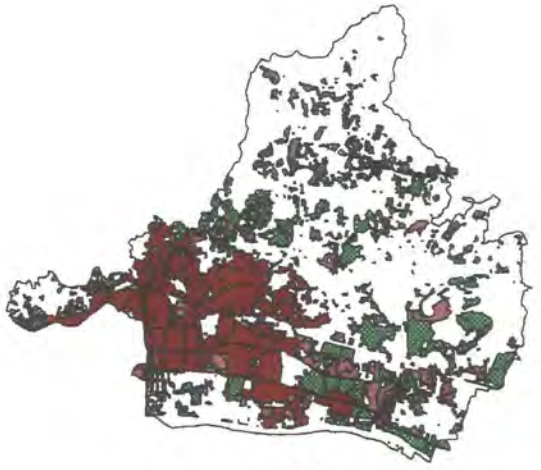


Figure 6-14. The trend of urban land use in space and over time.
(The dash lines indicate smaller percentages of land area in the 1-4 kilometre belt.)

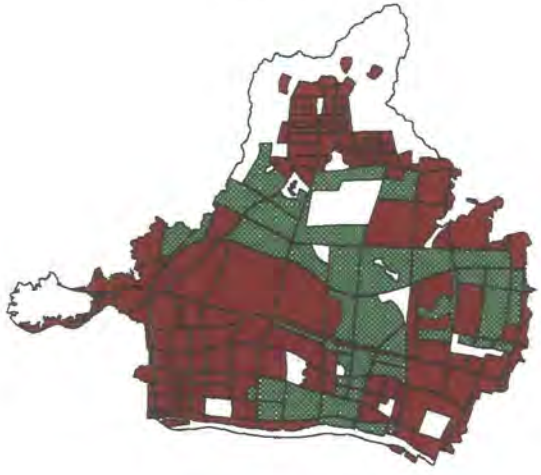
The industrial land varies complicatedly over time and space (Figure 6-16). Over the 2-8 kilometre belt, the share of industrial land changed little from 1973 to 1993, but will decrease sharply towards the year 2010. The second belt, from the 9 to 19 kilometres, experienced a rapid expansion of industrial land from 1973 to 1993, and will see further expansion towards the year 2010 in the two areas of the 9-13 and 17-19 kilometre belts. In the 14-16 kilometre belt where there will be little increase of



1973



1993



2010

Figure 6-15. The expansion of urban related area

industrial land, much of the land will be given to urban residential development (Figure 6-14 and 15).

The decreases in industrial land towards 2010 at the 2-8 kilometre belt is a result of two reasons. One is that industries will be moved farther away from the city centre. Another reason is that, in the plan for 1995-2010, some factories are included in urban land use because they occupy only the ground floor of residential buildings.

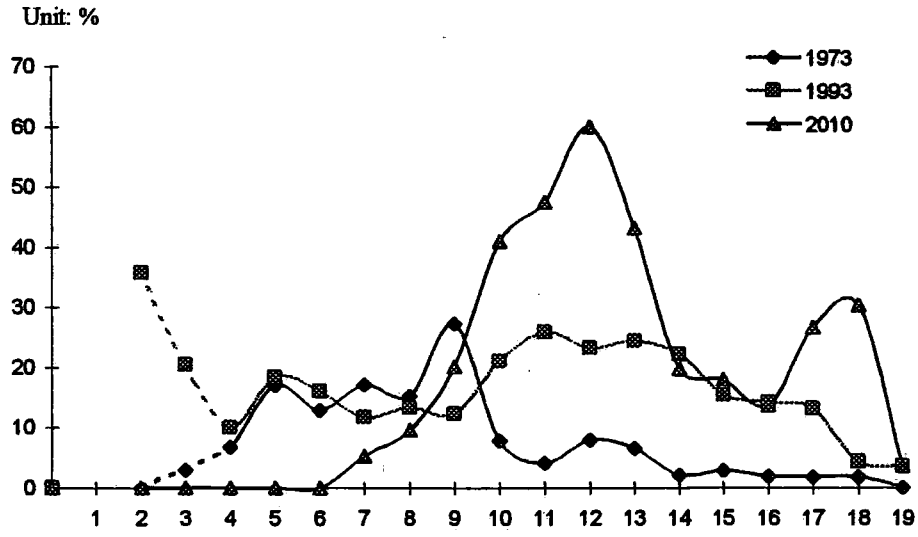


Figure 6-16. The trend of industrial land use structure in space over time

The spatial distribution of rural residential sites varies over time (Figure 6-17). Comparing the situation of land allocation between 1993 and 1973, the shares of rural residential land both increase and decrease as well in different belts. In the 2-3 kilometre belt near the city centre, rural residential sites were first merged into urban land use as a result of urban expansion. In the 4-5 kilometre belt the share increased slowly, but in the 6-9 kilometre belt it fell as a large rural residential area merged into urban land use. In the 11-18 kilometre belt rural residential land increased again

Transport land increases continuously in all kilometre belts (Figure 6-18). From 1973 to 1993, it saw a rapid increase from 1.3 % to 7.4 % in the 4-7 kilometre belt particularly. Further development can be seen in the 8-19 kilometre belt towards 2010.

Whilst the shares of urban, industrial and transportation land use continuously increase, the shares of arable and woodland use fall. It can be seen in Figure 6-19 that in the 5-12 kilometre belt arable land in 1993 became sharply less than that of 1973, with an average decrease of 25.6 %. In the 13-19 kilometre belt it also had an average decrease of 16.7 %. By 2010, only a little of arable land will remain in the 12-14 kilometre belt.

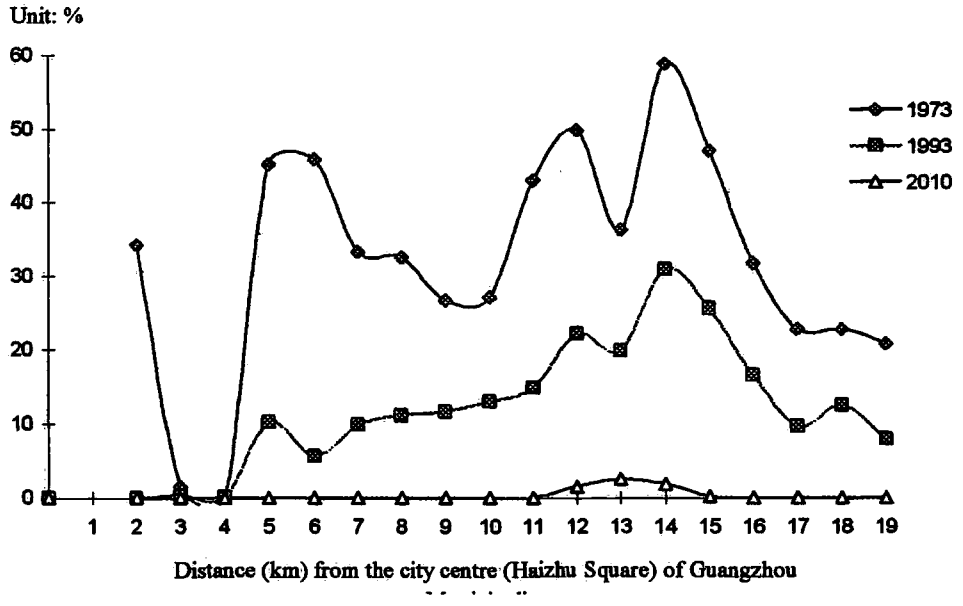


Figure 6-19. The trend of arable land use structure in space and over time

In the 6-11 kilometre belt the orchard land was turned to other utilisation as a result of the needs of non-agricultural land growth (Figure 6-20). It decreased from 4.9 % in 1973 to 3.8 % in 1993. However, in the 12-19 kilometre belt, further away

from the city centre, the share of the orchard land use increased from 6.1 % in 1973 to 12.7 % because some highly efficient orchards were opened to meet the needs in Guangzhou, but in the 2010 plan the orchard land use will apparently become zero.

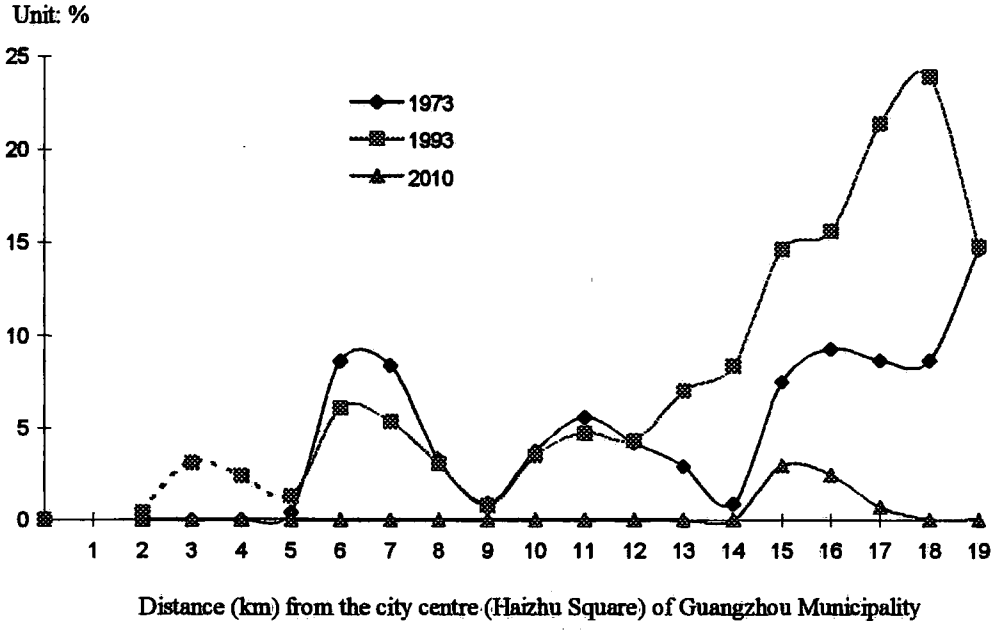


Figure 6-20. The trend of orchard land use structure in space and over time

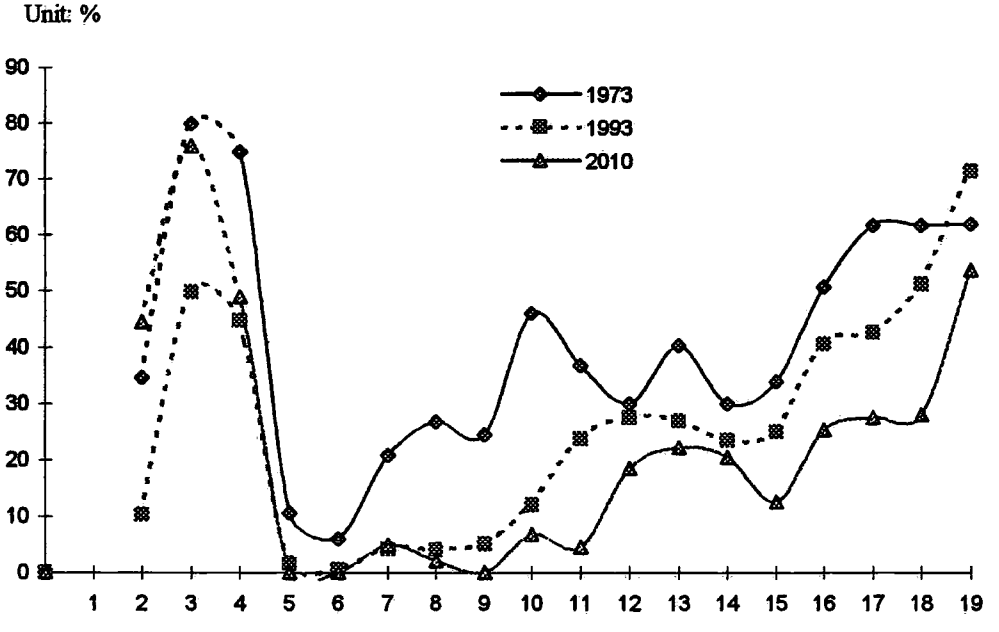


Figure 6-21: The trend of woodland use structure in space and over time

Another dominant example of urban expansion is the disappearance of woodland. In almost all of the kilometre belts the shares were sharply reduced from 1973 to 1993 and this trend will remain until 2010, except for the 5-9 kilometre belt in which the share will remain unchanged from 1993 to 2010 (Figure 6-21). This is partly because a sand and stone quarry will be rehabilitated into a garden.

The share of water body was roughly levelled off from 1973 to 1993 and will decrease towards 2010 (Figure 6-22). Apart from the Pearl River, a few reservoirs will be conserved, but most pools will disappear by 2010 (see Figure 6-6).

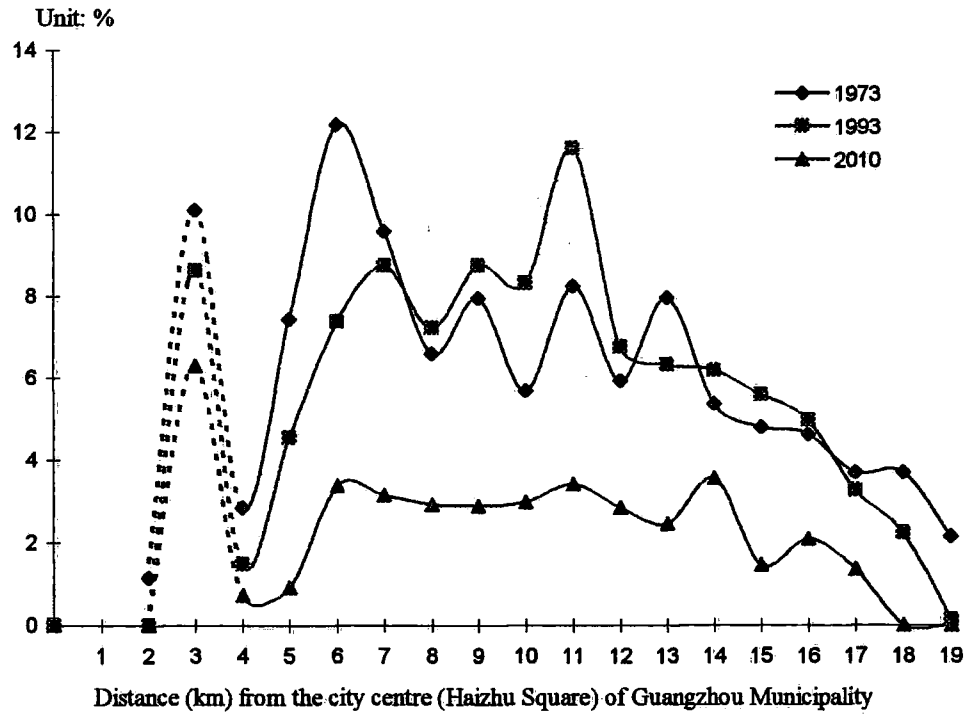


Figure 6-22. The trend of water body structure in space over time

6.4 Land use variations with slope

Slope is one of the major factors in evaluating land quality. The less the slope, the more convenient for farming, the smaller the cubic metres of earth work in water conservation, farmland capital construction and urban construction, and the higher the land utilisation values. This section firstly analyses the relationship between the land use changes and slope in different periods, then points out the impacts of slopes on the change of the land use structures in Tianhe's urbanisation process.

6.4.1 Slope analysis

The topographic characteristics in Tianhe District can be seen in Figure 6-23. Generally, slopes in most study area are less than 15 degrees (Figure 6-24, Figure 6-25). The areas with slopes of more than 15 degrees occupy 1720.4 ha, accounting for 11.5 % of the district. These areas are located around the central-north hills, the ring hills and the western part of Shahe Town. The areas with slopes from 6 to 15 degrees occupy 1949.8 ha, accounting for 13.1 %, which are sparsely distributed across the District. The areas with slopes of 0-2 degrees and 2-6 degrees which are suitable for farming, and factory and urban development, account for 9714.5 ha (65.1 %) and 1544.7 ha (10.3 %) respectively.

In the 2-4 kilometre belt, topographies with slopes of 6-15 degrees and higher occupy the biggest proportions with averages of 28.2 % and 15.7 %, respectively. This has resulted in the high proportion of woodland in this belt. From the 5 to 18 kilometre belts, the slopes of 0-2 degrees account for 66.1 %, declining to 33.2 in the

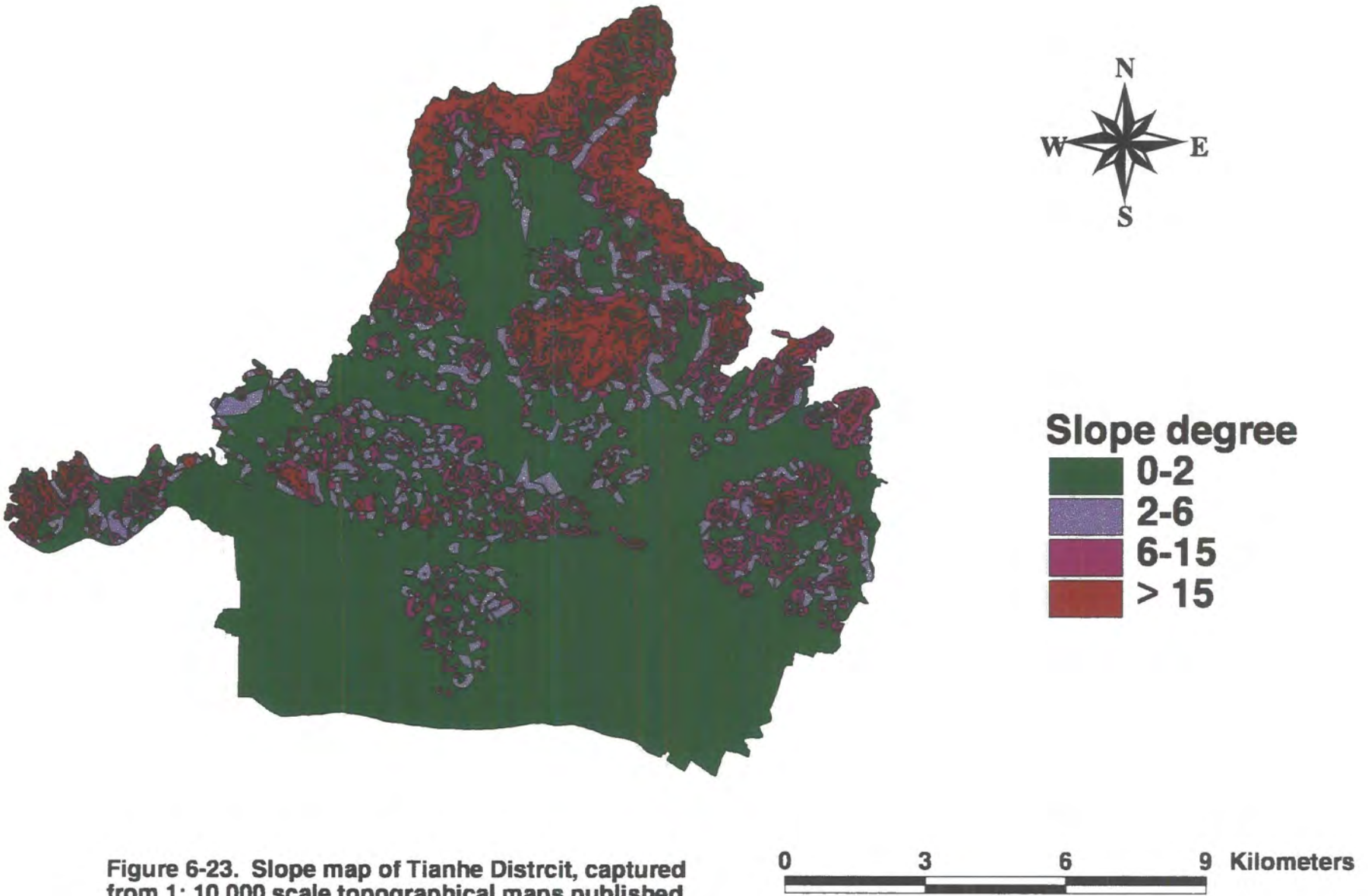


Figure 6-23. Slope map of Tianhe Distrcit, captured from 1: 10,000 scale topographical maps published by the Bureau of Survey and Mapping of PLA

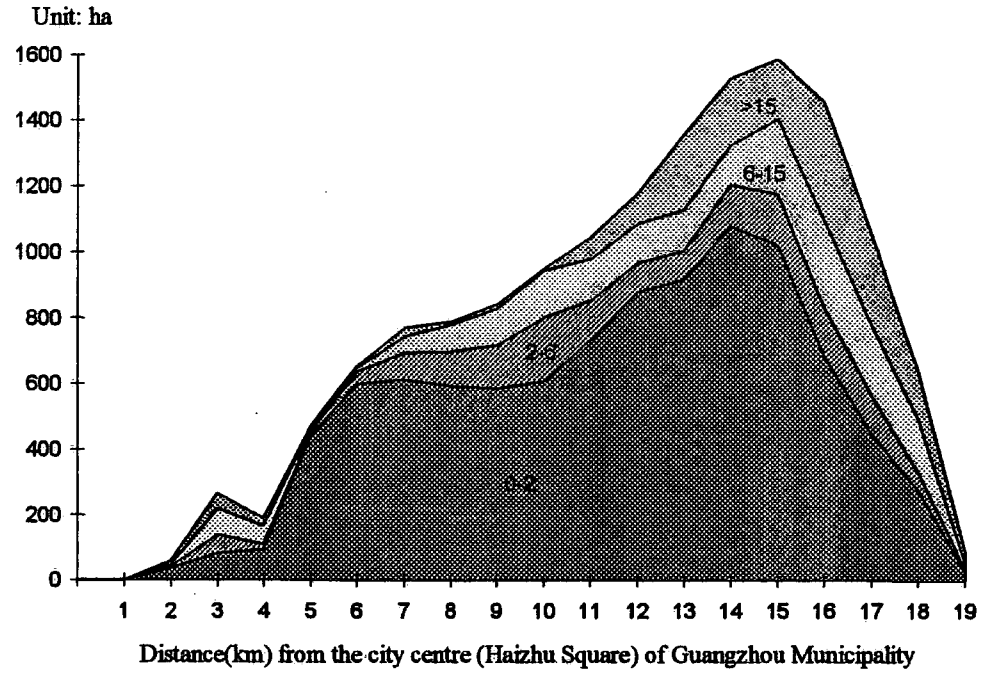


Figure 6-24. Slope variations with distance (value)

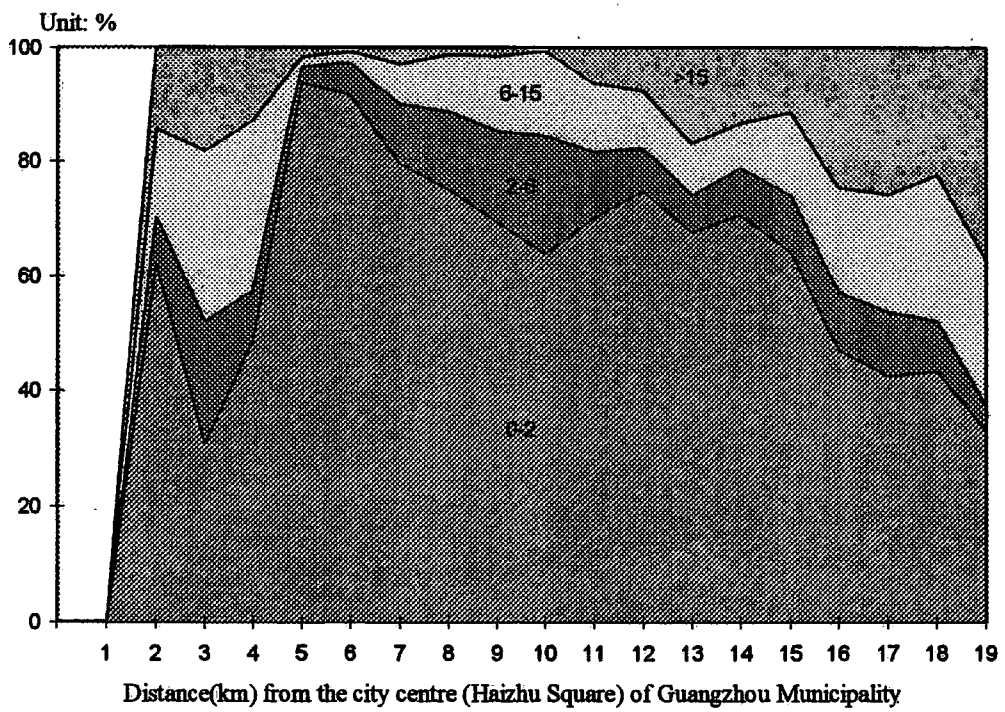
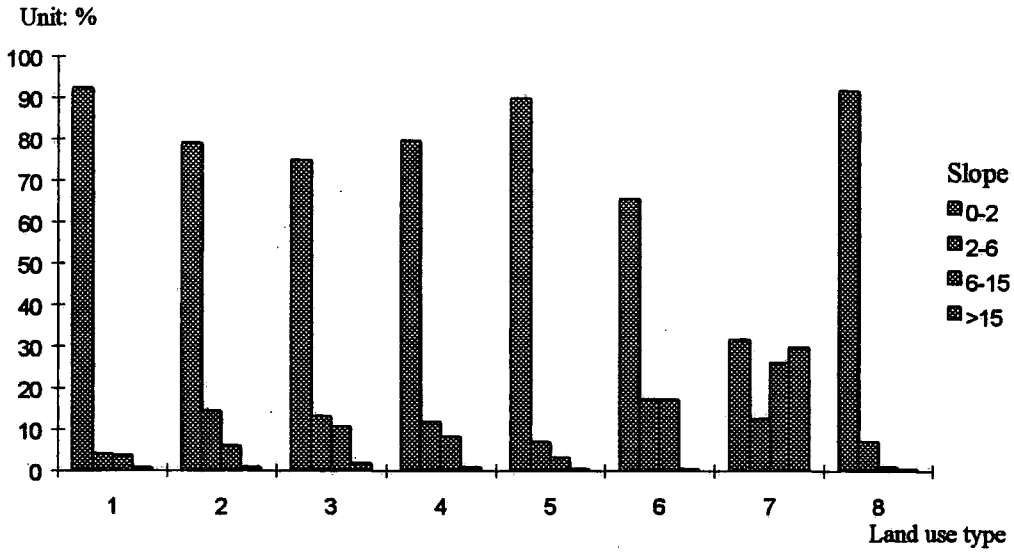
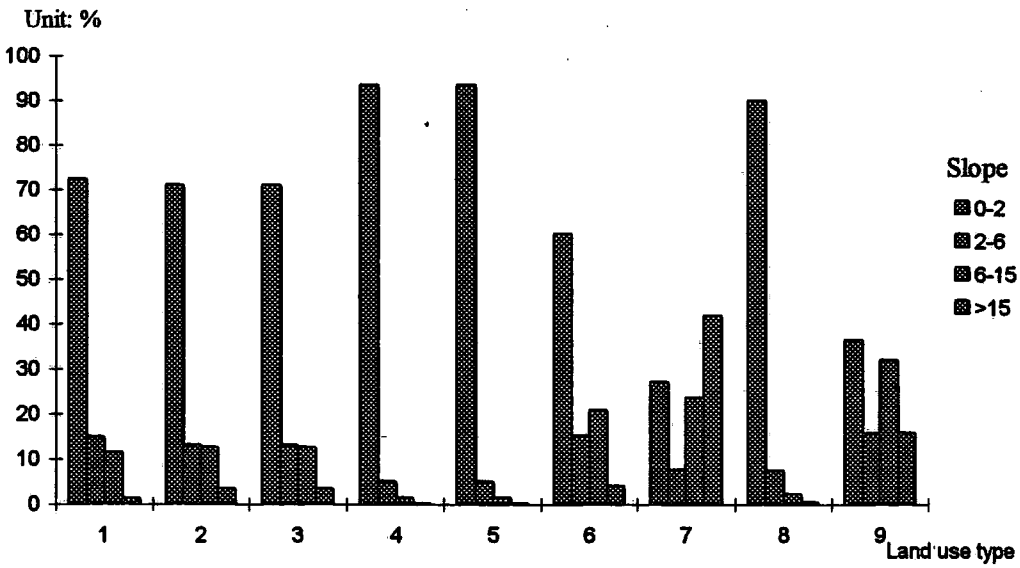


Figure 6-25. Slope variations with distance (percentage)



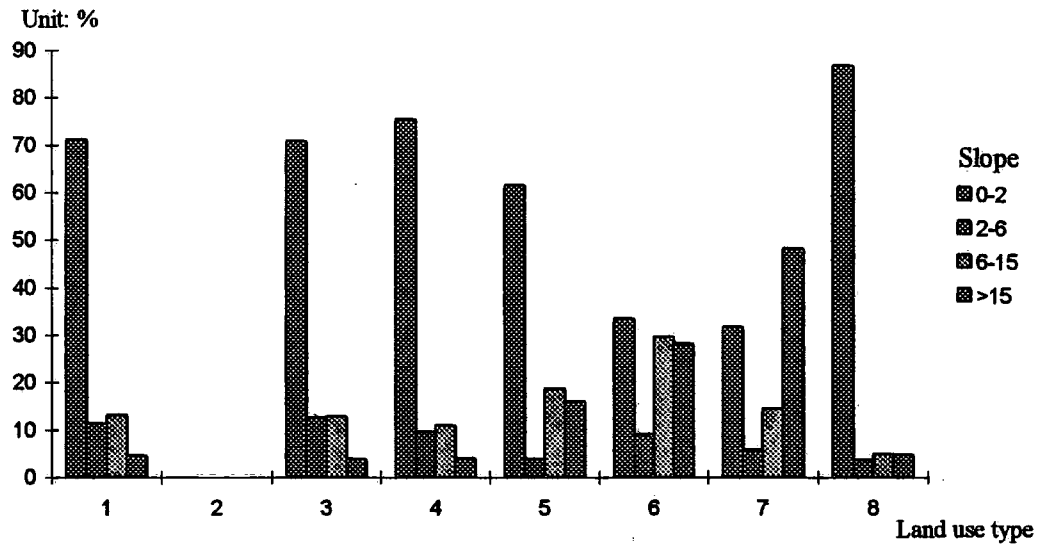
1	urban	6	orchard
2	rural residential	7	wood
3	industrial	8	water body
4	transport	9	unused land
5	arable land		

Figure 6-26. Land use variations with slope in 1973



1	urban	6	orchard
2	rural residential	7	wood
3	industrial	8	water body
4	transport	9	unused land
5	arable land		

Figure 6-27. Land use variations with slope in 1993



1	urban	6	orchard
2	rural residential	7	wood
3	industrial	8	water body
4	transport	9	unused land
5	arable land		

Figure 6-28. Land use variations with slope for the land use plan of 2000

19 kilometre belt. In contrast, the area with slopes of more than 15 degrees accounts for 1.7 % in the 5 kilometre belt, increasing to 37.1 % in the 19 kilometre belt. On the whole, the topographic slopes increase with changing distance from the plain of the city centre to the peripheral hill belts.

6.4.2 Land use variation with slope

Through the comparative analysis on Figure 6-26, Figure 6-27 and Figure 6-28, two common characters are noted as follows. One is that agricultural, urban, residential, industrial, transport and water bodies are mostly distributed in the topographies of 0-2 slopes, occupying more than 80 % of the same types of land use totals. Another character is that woodland is distributed in all four slope classes in Tianhe District but their proportions in the slopes of more than 15 degrees increase over time.

Figure 6-29 illustrates that the urban and industrial land use are extending towards steeper slope areas. The urban land on slopes of more than 15 degrees will increase from 29.3 ha in 1993 to 326.3 ha in 2010, but the industrial areas will increase from 85.5 ha in 1993 to 268.3 ha in 2010.

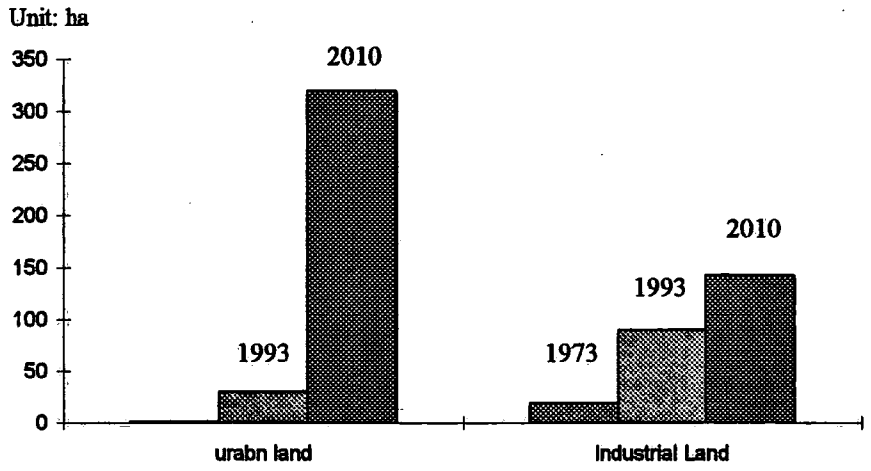


Figure 6-29. Urban land use in high slope (>15^0) area in different years

6.5 Conclusion

This chapter has discussed in detail the dramatic changes of land use in Tianhe District from agricultural region to rural-urban fringe, and further to a fully urbansied district. With this functional shift, the spatial structures of land use in Tianhe District have changed accordingly. In chapter 7, the impacts of several factors such as different policies, economic changes and population growth, will be discussed.

Through the analysis in this chapter, it can be seen that the city centre has expanded and will continue to expand with the development of urbanisation, accompanying the decrease of agricultural and woodland. From the viewpoint of distances from the city centre, the changes of land use have taken on a systematic basis, which could be predicted by distance decay theory. From the topography analysis, except for the north hilly area limiting the urban expansion, most of the areas are floodplain suitable for different types of land use and favourable for the eastward urban development.

CHAPTER 7:

RURAL-URBAN FRINGE DEVELOPMENT AND EVALUATION

7.1 Introduction

In this chapter, different factors that have caused land use changes in Tianhe District are discussed based on the analysis in Chapter 6. Firstly, according to the analysis of land use changes over time and space, the indexes of variation in land use structure are used to measure the general patterns of land use change, finding out the nature of the allocation of different land use types in Tianhe District. Secondly, factors discussed concern the physical and locational conditions, economic development, urban expansion, transportation, and policies and regulations that have resulted from the above changing trends. Finally, in order to verify the rationale of land use planning for 2010 of Tianhe District, a comparative analysis for the development of the rural-urban fringe globelly is carried out.

7.2 The characteristics of land use patterns in Tianhe District

Land use in the rural-urban fringe is a transition between the urban land use and the rural land use. It is such a transition that is especially apparent in land use

structure and allocation. According to the analysis in Chapter 6, it can be seen that land use structure and spatial allocation in Tianhe District has brought about dramatic variations in the evolutional process from traditional rural area, and the rural-urban fringe to the urban area. The major characteristics are manifested in the following aspects.

7.2.1 Changes in diversity of land use structure

As a typical agricultural area in 1973, land use structure in Tianhe was relatively simple but it became diversified when it was in the stage of the formation of the rural-urban fringe in 1993. In future it is expected to become simple again in the stage of post-urbanisation. During the transitional period of the rural-urban fringe, different types of land are transferred within the fringe and various combinations of land use types are formed. Among the different distances, various combined relationships between different land use types have also been developed. The further the distance from the city centre, the less the share of non-agricultural land becomes. This trend was clearly apparent in the land use evolution of Tianhe District from 1973 to 1993. In order quantitatively to analyse the diversity of land use structure and the spatial distribution of Tianhe District, a diversity index of land use structure is applied (H) (Cheng, 1995);

$$H = \sum_{i=1}^{n} p_i \ln p_i$$

Where, H: represents the diversity index of land use structure;
P_i : represents the share of the *i* type land in the total land area;
n: represents the number of land use types.

In the above formula, the larger the H value, the more diverse is the land use structure observed. The diversity indexes of land use structure of Tianhe District was

1.48 in 1973, 1.97 in 1993 and will fall to 1.34 in 2010. This clearly illustrates the trend of change in land use structure from simple to complicated, then to simple as the urban area expanded across Tianhe District. Figure 7-1 shows the spatial variations on the diversity indexes of land use structure in different periods.

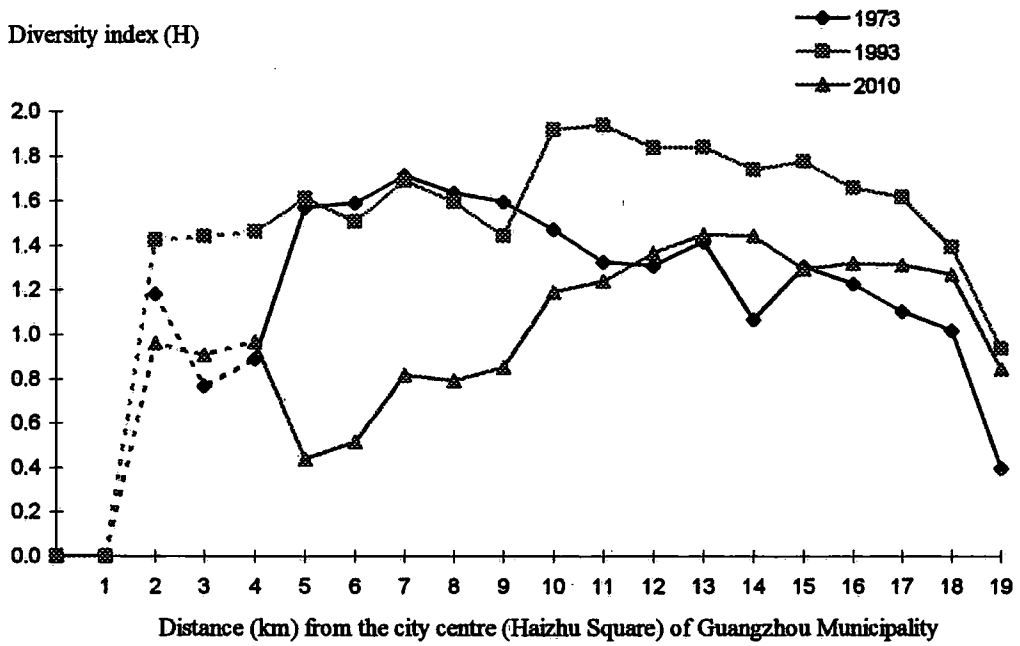


Figure 7-1. The diversity indexes of land use structure in different periods

Generally, the diversity indexes of land use structure from 1973 and 2010 are less than those of 1993. Particularly, in the 5-9 kilometre belt, the H values of 1973 and 1993 are much greater than those of 2010. These belts are located from the far West and Southwest of the Tianhe Gymnasium and Tianhe Railway Station which were characterised by a preliminary urbanisation whilst they were the core belts of diversification operations of Tianhe District in 1993. The agricultural production, residential housing and a certain amount of industry were concentrated in these belts.

7.2.2 Transformation of the land use types

During the process of urbanisation in Tianhe District, its land use structure was not stable and possessed the dynamic characteristics of a clear disequilibrium. Tianhe District was developed from a traditional rural area in 1973. In this period, the land use types in Tianhe District underwent a dramatic transformation from a simple structure of traditional arable land to a complex structure of mixed rural and urban land use. Towards 2010, the land use structure is expected to become simple again as urban land use dominated the District. During these periods, the arable land has changed from solely grain planting to multi-crop and vegetable planting. At the same time, different urban lands expanded rapidly outward from the centre of Guangzhou Municipality. The traditional rural land use structure in the early stage entered into a situation when the arable and wood lands were into urban land use (residential, industrial, housing, commence and service). Eventually, the allocation of all of these land use types will reach a new equilibrium.

Table 7-1 clearly illustrates the characteristics above. The columns in the table are data of land use in 1993 whilst rows are those in 1973. It shows the transformation dynamics of different land use types. About 60% of the arable land in 1973, for example, were transformed to orchard and other land use types which are related to urban development (urban land, rural resident sites, industries and road). Also, nearly 40% of the woodland was transformed into orchard and other urban land. There were also some complicated transformations between other types of lands. It is necessary to note that the same transformation occurred between urban land, industries and rural residents. This transformation illustrates the character of urban sprawl and industrial allocation changes found at the primary stage of the urbanisation.

Another index can be obtained from Table 7-1 from which one can measure land use changes. This index is called the ratio of land type transformation.

$$\text{Ratio of the land type transformation} = \frac{|\text{Total land area} - \text{untransformed land area}|}{\text{Total land area}}$$

Through calculations, the ratio of the land type transaction from 1973 to 1993 is 45 %. This clearly points out the high and rapid transition of land use in Tianhe.

Table 7-1. Transformation of land use type between 1973-1993 (Unit: ha)

1973	1993									
	10	20	30	51	52	53	60	70	80	Total
10	2137.1	509.7	316.8	568.9	351.5	1121.7	235.3	259.8	48.6	5549.4
20	115.4	329.0	93.7	12.1	27.3	155.5	13.7	27.3	16.6	790.7
30	127.3	462.1	3052.0	642.8	191.9	833.5	62.6	94.3	161.8	5628.2
51	0.0	0.0	0.0	68.4	13.8	5.6	6.5	0.3	0.0	94.6
52	2.9	5.4	11.4	378.2	223.6	86.4	12.0	8.4	0.2	728.5
53	14.0	9.9	61.5	574.9	72.6	284.8	53.3	15.0	1.9	1087.9
60	8.6	3.1	5.9	17.7	7.1	18.5	35.7	1.0	0.4	98.0
70	53.0	18.9	34.7	71.8	61.6	112.2	26.2	555.8	2.6	936.8
80	5.4	0.4	0.8	1.9	3.7	2.4	0.1	0.4	0.0	15.3
Total	2463.7	1338.5	3576.9	2336.8	953.2	2620.6	445.4	962.4	232.1	14929.4

Table 7-2 shows the potential land transformation in Tianhe District from 1993 to 2010. Its transformation will accelerate and the ratio of the transformation will reach 70%. Viewing from the overall trend, a large amount of rural land will have been transformed into lands related with urban development. Moreover, the transformation still takes place among the urban, industries and transport. All of these transformations fully illustrate the complex character of the changes of land use types.

Table 7-2. Transformation of land use type between 1993-2010

1993	2010									
	10	20	30	51	52	53	60	70	80	Total
10	34.1	13.0	95.0	1213.7	0.0	858.1	247.0	2.7	0.0	2463.7
20	7.3	27.7	167.8	592.6	0.0	421.7	112.6	8.8	0.0	1338.5
30	35.2	34.3	1667.9	1016.8	0.0	608.2	165.9	48.5	0.0	3576.9
51	0.0	0.0	9.7	1853.3	0.0	270.8	202.6	0.2	0.0	2336.7
52	0.1	7.7	40.8	556.4	0.0	254.4	91.7	2.1	0.0	953.2
53	2.4	3.5	266.5	1195.1	0.0	915.6	222.4	15.2	0.0	2620.6
60	0.0	0.0	33.6	250.5	0.0	122.4	38.8	0.0	0.0	445.4
70	0.8	3.0	68.2	372.4	0.0	167.1	60.5	290.3	0.0	962.4
80	2.9	0.0	51.5	55.1	0.0	107.6	13.7	1.2	0.0	232.1
Total	82.8	89.2	2401.1	7106.0	0.0	3726.1	1155.3	369.0	0.0	14929.5

10: arable-land
20: orchard
30: wood
51: urban
52: rural residential
53: industrial
60: transport
70: water body
80: un-used

On the whole, the transformation of land use in Tianhe District underwent three stages from the traditional agricultural area, rural-urban fringe and to urban area. Table 7-3 outlines the above characteristics.

Table 7-3. The transformation of land use types in Tianhe District

Territorial types	Traditional agricultural area	Rural-urban fringe	Urban area
Transformation stage	1	2	3
Major land use types	Wood Arable	wood Industry arable urban orchard	urban industry wood
H values	Low	high	low
Landscapes	Plantation	meticulous agriculture industry and commerce	industry commerce service
land users	Peasants	peasants, urban residents, developers and builders	urban residents

7.2.3 The allocation characteristics of land use in rural-urban fringe

The allocation of land use in Tianhe District varies over time. Generally speaking, with the urban expansion, the lands related to urban development expanded outward, whilst the agricultural and woodlands decreased with the distance from the city centre. There are different characteristics during the stages of the formation period (1973-1993) and the development period (1993-2010) in Tianhe District.

7.2.3.1 The formation period

During the formation period of the rural-urban fringe, urban expansion first took place in Shahe Town, the nearest part of Tianhe District to the city centre of Guangzhou Municipality. It then went southward from Shahe Town and along the north side of the Pearl River. Finally, it expanded eastward along both sides of the Guangzhou-Shenzhen railway line. This expansion is the spreading pattern of so-called pancake-making (Guo and Ding, 1995). The most important expansion started with the construction of the Tianhe Gymnasium in 1986 and the Tianhe Railway Station in 1990 in the south of Shahe Town, which then merged into a section of the Yuancun-Dongpu industrial area. In the North of Shahe Town, some industries and Universities had been allocated before 1973 and since then, due to the advantage of transport, urban sprawl has increased rapidly. Generally, the urban expansion during this period spread around two lines (the Pearl River and railway lines) and three points (Tianhe Gymnasium, Shahe Town and Dongpu Town).

During the transformation period, owing to the scattered allocation of the urban land, especially the industry and residential lands, the arable and wood lands were separated and cut into several narrow belts, some of which were scattered into

the different urban lands and presented a complicated pattern of land use. The woodland shrank northward towards the hilly area. With the enlargement of the needs for fruits for the residents in the city, the orchard was developed rapidly becoming part of the high-volume agriculture.

Owing to the lack of effective land use planning during this period, the allocation of different land uses was largely in disorder. As a result, land use types became complicated and the comprehensive index of its land use structure (H) was relatively high.

7.2.3.2 The development period

During the planned period, the urban region will develop basically in three areas. The first is the urban core axis by the line of the Tianhe Gymnasium-Tianhe Railway Station. The lands are mainly used for urban residential housing, science and technology industries and commerce activities whilst most traditional industries will move farther away from the city centre. The second area is centred at Dongpu Town and to its south where residential housings is dominant. The third is at the northern area of Tianhe District around Longdong village, that is to be used for tourism and preserved for urban development in the future. The industrial enterprises are to fill the 'r-shape' corridor of the above three areas.

It is notable that the expansion of the rural residential land use is one of the leading factors of the urban expansion during the formation period of the rural-urban fringe. At the same time, some rural residential area in the western part of Tianhe District were converted to urban land utilisation.

In the development period, the sparse lands, especially the arable land within

the urban area, are to be recruited and developed into the urban area and industrial area. As a result, the stripped arable lands will nearly disappear. The wood land will shrunk further in the northern area and the two high altitude belts. The orchard land will turn from large size of the rural-urban fringe period to a small size and will almost disappear in the post-urbanisation period. This points out another characteristic of land use change in Tianhe District. With the urbanisation, the orchard land will give way to the higher value-added urban land use.

In summary, it can be seen through the analysis of this section that the urban development is taken at the price of the decreasing arable land, woodlands, and presents different patterns at different stages. The force of this change is derived from the urban development of Guangzhou, population growth, and policy and law changes, and the geographical location of Tianhe District. The impact of different factors on land use changes will be discussed in the following section.

7.3 The analysis of factor

Land use type, structure and functional evolution of the rural-urban fringe are the results of internal forces from its socio-economic development and other different external conditions such as the physical conditions. This section aims to find out the formation mechanism and processes by analysing the impacts of some major factors on land use in Tianhe District. Moreover, it proposes to enforce the rational exploitation, planning and utilisation of the land resources in the rural-urban fringe.

7.3.1 Location, urban sprawl and land use

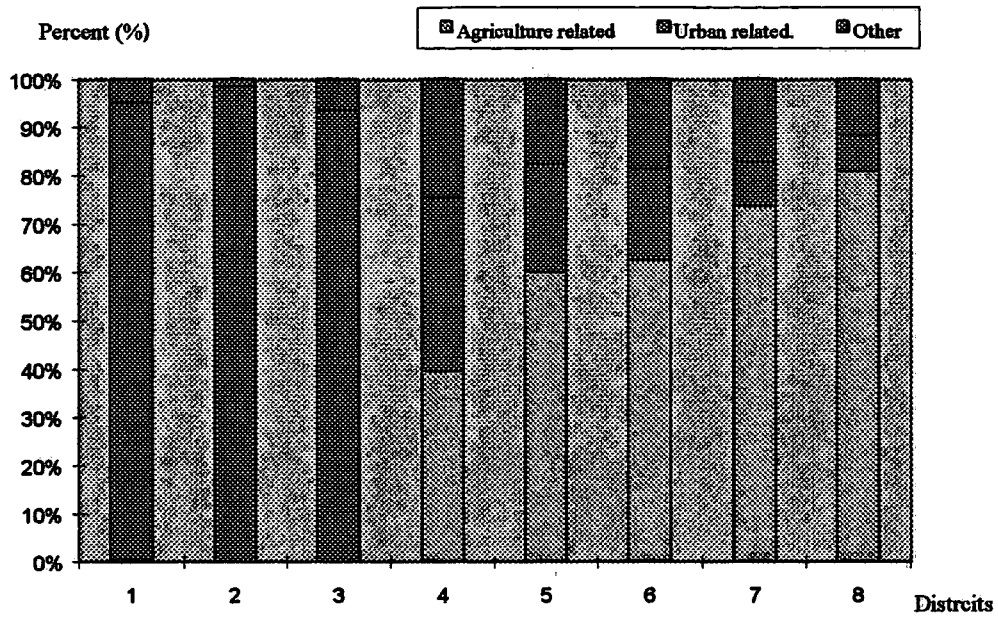
In chapter 3, the geographical location, physical conditions and the development history of the Guangzhou Municipality and the Tianhe District were discussed. Generally, the old Guangzhou city originates in Liwan, Yuexiu and Dongshan Districts (Figure 4-3). With the economic development and population growth, the city needed lands for urban construction. However, under the influence of different physical and socio-economic conditions, the future urban expansion of Guangzhou Municipality will be forced to expand outwards to the northwest and southeast from the city centre. The major reasons are as follows:

1. The old city region has been highly populated. According to Figure 7-2, the urban land shares have accounted for more than 93% of the three old city districts (Liwan, Yuexiu and Tianshan). This illustrates the limitations on land supply to fulfil the need of urban development in these districts.

2. The Pearl River cut off the south region of the city. As a result of unfavourable transport, this has been the backward region of Guangzhou city for years. Its further development costs are very high.

3. The Northeast region of Guangzhou is hilly and mountainous. The topographical conditions are not suitable for the urban construction.

Therefore, one of the potential areas for further urban expansion is on the floodplain area in the north of the old city. The topography of this area is relatively flat, and transport is both favourable and suitable for urban development. Another area of potential for urban development is Tianhe District that is close to the main part, Huangpu Harbour.



1.Dongshan
2.Yuexiu
3.Liwan
4.Tianghe
5.Haizhu
6.Fangcun
7.Huangpu
8.Baiyun

Figure 7-2. Land use type variations in districts in Guangzhou Municipality

By 1993, the southwestern part of Tianhe District is already part of the old city. It is strongly influenced by the radiation effects of urban development. Its locational condition is also advantageous. The adjacent lands to the city centre are firstly transformed into the urban land. The constructions of the Tianhe Gymnasium and Tianhe Railway Station have accelerated the transformation process. The eastern part of Tianhe is suitable for the development of warehouse, stock, docks and related industries, due to its closer proximity to the main part.

There are a number of universities, colleges and institutes concentrated in Tianhe District, which is favourable for the development of high-tech and light

industries. This factor helps speed up the transformation of the agricultural land into urban land.

7.3.2 Economic development and land use

The booming of the economy leads to more job opportunities and requires the development of shop and other urban service industries. The economy in Guangzhou has been increasing since 1979. Figure 7-3 and Figure 7-4 illustrate these exponential economic increases in Guangzhou city and Tianhe District. The economy in Guangzhou as a whole increased in the 1980s, which led to the urbanisation in Tianhe District starting from the beginning of the 1990s. These trends are expected to continue into the next decade, thus, it is clear that there is an urgent need for land for development.

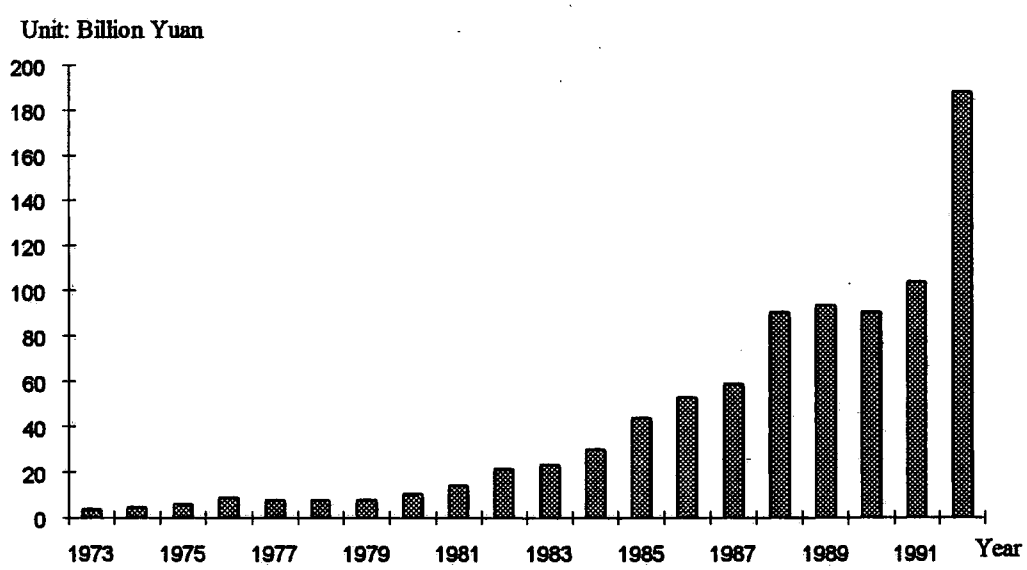


Figure 7-3. Economic situation in Gugangzhou Municipality in 1973-1992

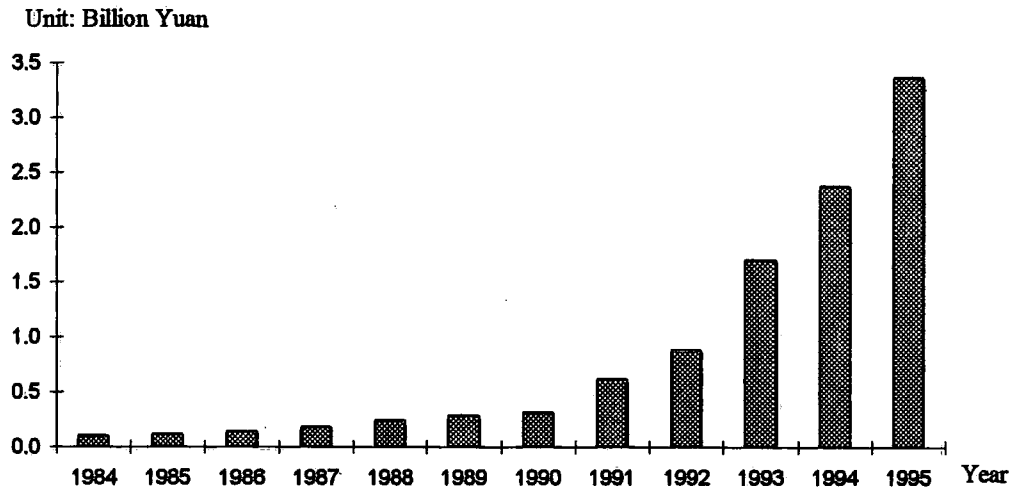


Figure 7-4. Economic situation in Tianhe District in 1984-1996

Another major factor of the economic development is the spatial adjustment of industrial structures. Over space, from the city centre to the peripheral areas, the shares in different industries change through time.

These changes are shown in Figure 7-5, which points out the temporary variations of three industries. In the formation period of rural-urban fringe in Tianhe District, the share of its primary industry declined. In the beginning of urbanisation, the expansion of the industrial land is the leading factor of the outward expansion of the rural-urban fringe, especially the expansion of secondary industry, which is followed by the service industry. With the advancement of the urbanisation, service industry develops rapidly, and the primary and secondary industries have to move outward and give way to the development of service industry and urban housing.

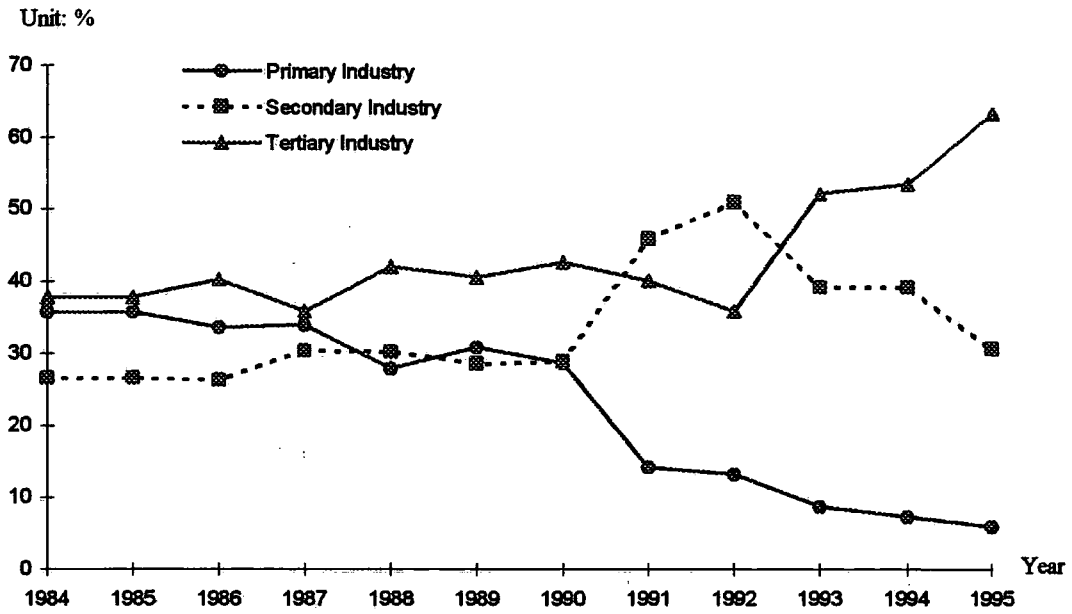


Figure 7-5. Industrial structure in Tianhe District during 1984-1995

7.3.3 Population and land use change

Ideally population growth should be accompanied by an increase of employment opportunities and the building of residential housing, hence causing a great pressure on land use.

It can be seen from Figure 7-6 that the population of Guangzhou has increased at a linear pattern from 1973 to 1993 with an annual average growth of more than 2.0%. According to Figure 7-7 and Figure 7-8, the population of Tianhe District has grown more swiftly from 1984 to 1993 and its annual average growth rate is greater than 3.0%. Statistically, from 1980 to 1993 the population natural growth rate of Guangzhou is 1.13% (BSG, 1994) whilst that of Tianhe District is 1.28% (BSTD, 1994). The reasons of the population rapid growth are as follows:

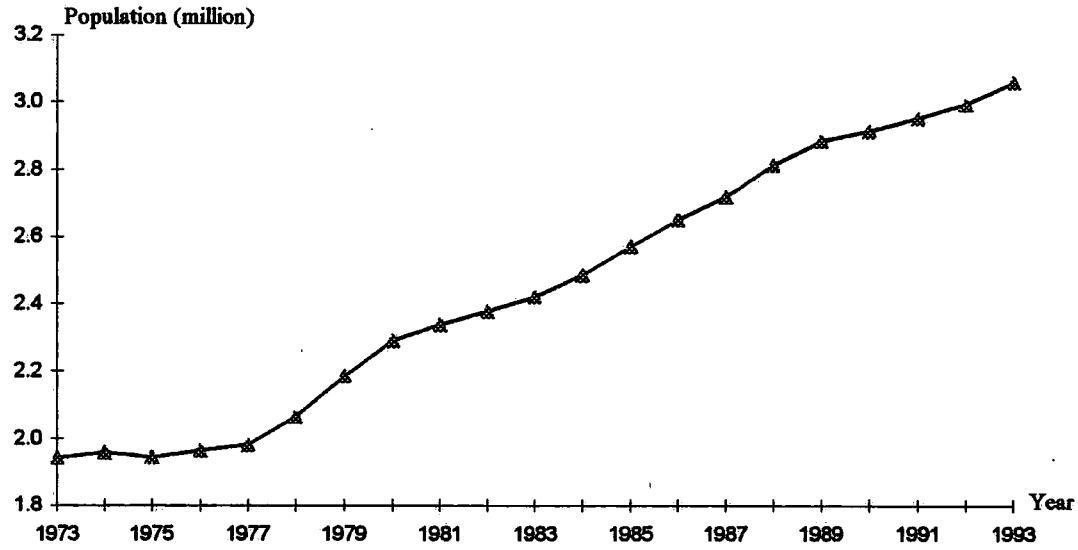


Figure 7-6. Population in the Guangzhou Municipality during 1973-1993

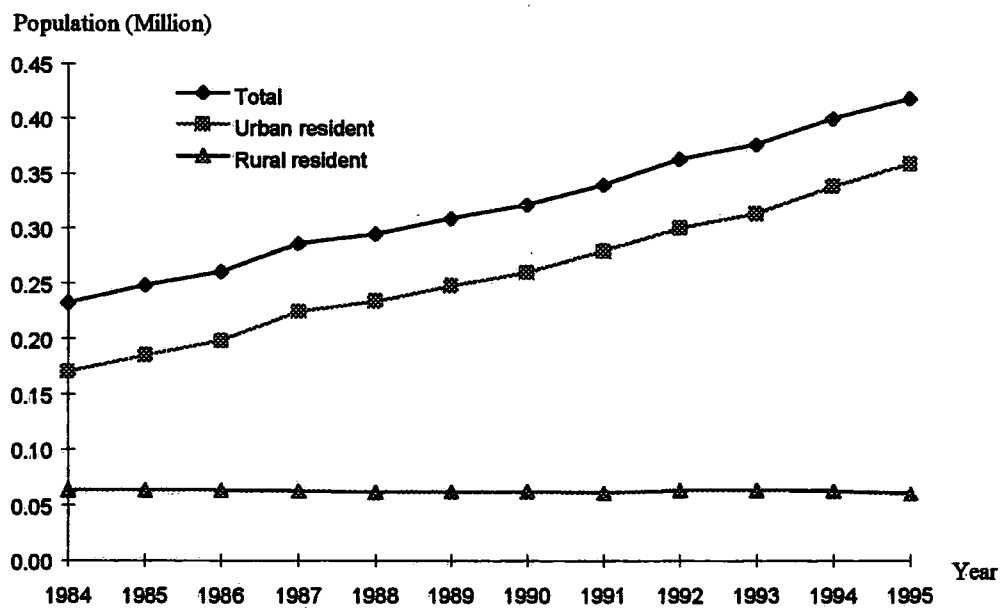


Figure 7-7. Population in Tianhe District during 1984-1995

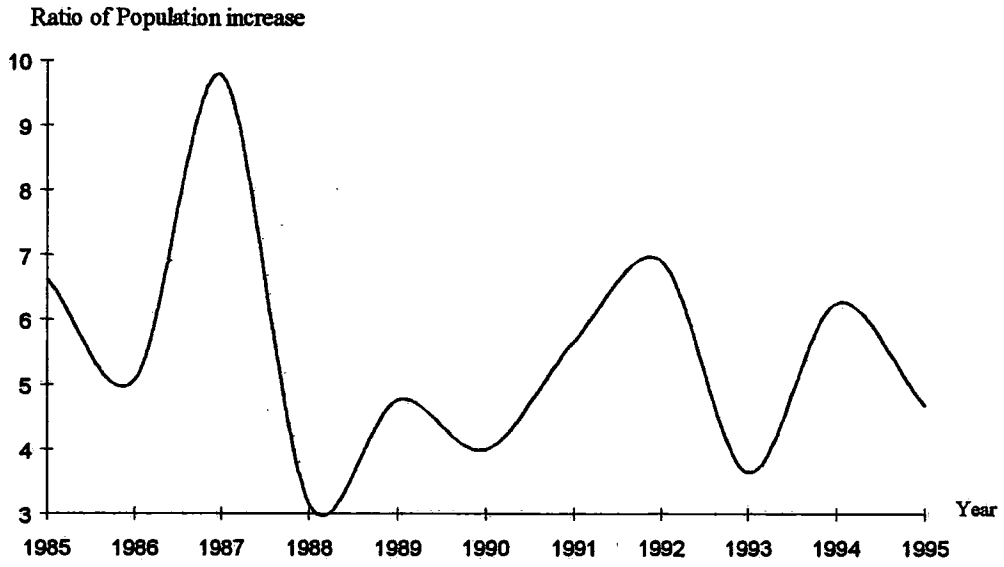


Figure 7-8. Ratio of population increase in Tianhe District during 1985-1995

1. Guangzhou is the largest city in Southern China. Since carrying out the opening up policy, a substantial amount of population, material and goods, and capitals have flowed into Guangzhou from its domestic and international counterparts. Therefore, the incoming population grew at a large scale and kept to increase continuously, in 1989, for example, it reached 311,000 people.

2. Whilst the population in the old districts of the Guangzhou urban area was highly dense with nearly 40,000 persons per kilometre on average, the four fringes such as Tianhe District possess less than 2000 person per kilometre. The urban population is necessarily to spread outward from the city centre. Tianhe District as a developing rural-urban fringe is the potential and major target of population emigration from the old city as a result of its relatively spacious land and greater development chances. The large amount of inflowing population needs accommodation and places for running restaurants and canteens, services, and investing in estate industry.

Table 7-4. The population density in Districts of Guangzhou Municipality

Areas	1983		1986		1989	
	Area (Km^2)	Density (person/km^2)	Area (Km^2)	Density (person/km^2)	Area (Km^2)	Density (person/km^2)
Old Districts						
Dongshan	14.6	29238	17.2	28433	17.2	31387
Yuexiu	8.9	53992	8.9	55034	8.9	54625
Liwan	11.8	45451	11.8	46182	11.8	46627
Haizhu	19.1	25940	90.4	7018	90.4	7482
Rural-urban fringes						
Huangpu	121.7	1081	121.7	1165	121.7	1259
Tianhe			108.3	2424	108.3	2866
Baiyun			1042.7	637	1042.7	659
Fangcun			42.6	3138	42.6	3293

Source: BPGM (1994, 8)
* haizhu District has been disadvantagous as it is cut off from the city centre by the Pearl River.

3. Shown in Figure 7-8, the agricultural population has kept to more than 500,000. According to the statistical data, during 1980-1993, the natural growth rate of the agricultural population increased by 1.3 %, which was more than 0.8% of the urban population growth (BSTD, 1994). However, in the agricultural statistical data the agricultural population is relatively stable. This illustrates that the inflowing population was added into the urban population.

Generally, population from other districts of Guangzhou have moved into Tianhe District, and a substantial number of agricultural residents have become urban residents. All of these population changes mean that the region undoubtedly needs much space for them, thus pushing the rapid transformation of the non-urban land into the urban land.

7.3.4 Transportation and land use

The modern transport development is also one of the major factors influencing the formation of the rural-urban fringe. At present China is at the level of quasi-

mechanisation and cities mainly develop the large-volume centripetal transport system, hence limiting the urban development model of the satellite-cities (Gu and Ding, 1995). The urban expansion in Tianhe District has followed China's model. Axised by the centre of the Tianhe Gymnasium and the Tianhe New Railway Station, a network-like modern urban road system is developing. The axised belts are also the core areas during the formation period of the Tianhe fringe, concentrating on development of housing, enterprising and schools. Therefore, the transport condition is an important factor of Tianhe outward expansion.

7.3.5 Policy, laws and land use

In China, the policy factor already has an impressive influence on the spatial expansion of the rural-urban fringe. In the case of Guangzhou, especially in Tianhe District, some actual influences are embodied as follows:

1. The macro-economic policy

In the overall development system of China, Guangzhou is the political, economic and cultural centre of Southern China and the capital of Guangdong province. Its industries are heavily concentrated and urban radiation power is very strong. Since the open-door policy in 1979, Guangzhou has been one of the 14 open cities, and has thus developed rapidly. This policy has enhanced its economy, and thus its urbanisation. In 1993, economic growth rate was abnormally high (Liang, 1996) This is due to the result of Deng Xiaoping[1]'s inspection in South China in 1992,

[1] Deng Xiaoping, 1904-1997, the major ex-leader of China, surveyed China's Special Economic Zone-ShenZhen in 1992, emphasising on accelerating economic construction, hence a substantial of development zones were established. For 5 years, China has built up 5000 zones at different scales accepting the land areas of 230,000ha.

emphasising an acceleration of the economic development. Afterwards, Tianhe Industrial Park, occupying about 4 square kilometres of land area, and Tianhe High-Tech Area, occupying about 3.8 square kilometres of land area, were defined.

2. The industrial allocation policy

To tackle the heavy pollution of the old factories in the centre of Guangzhou, the government of Guangzhou strictly limited the expansion of these enterprises and forced them to move out of the centre at the end of 1980s and the early 1990s (Liang, 1996). These enterprises were mainly moved into the rural-urban fringe. In Tianhe District, these enterprises were allocated to develop.

3. Specific policy

In most of the past 50 years, land in China were free for development. Each land user often sought to occupy much more land for its own benefit. Also, it was very difficult to transfer the land rights until 1986. This phenomenon did not turn out well until China's government carried out policy of transferring of land use rights (IFTESAC, 1992). Even so, the waste and uncultivated land pervasively existed when the arable land was transferred into urban land use.

Another factor, which resulted in the disordered allocation in the rural-urban fringe, is that China has been lacking in effective land use planning. Different government departments (for example, the Planning Commission, the Economic Commission, the Bureau of Planning, etc.), had rights to enforce their own planning and recruitment of land without united co-ordination. The Law of Land Administration of the PRC, released in 1986, required different levels of authorities to

develop land use planning, but this regulation has not achieved the expected results. It seems that land use planning did not have any effect on land use at different levels. Tianhe District for instance did not draw up its first land use plan until 1994. This is one of the reasons that land use allocation looks disordered during the evolution of the rural-urban fringe of Tianhe District.

7.4 Future perspectives

7.4.1 Assessment on the land use planning of the Tianhe District

Through the analysis of the above two sections, the characteristics and genesis of the rural-urban fringe of Tianhe District can be seen. With respect to the planning of land use in Tianhe District, its principle clearly aims to make the most use of the macro-scale controlling and adjusting functions of the government in the administration of land use, and to transform Tianhe District into a new urban area with clear functions of housing, commerce and industry, based on the present development model. Several characteristics can be seen from this planning.

1. The urban expansion undergoes a pattern of 'spread' from the city centre. Although the functional division of industrial area and urban areas are considered, they will expand in a north-south direction and form a new city centre of Guangzhou on the ground of the original urban area.

2. The urban expansion takes place at the expense of occupying the arable land and woodlands, and the latter will disappear in the broad southern area.

3. Although an area of conservation of green wood is planned in the northern area, the controlled area of the woodland is small and narrow; the 'r-type' distribution of industrial areas will result in new environmental pollution. In addition, the

aggregate urban expansion will bring about traffic-jams and other urban disorders, which have appeared and showed a growing trend when the author made the field survey.

In general, either during the formation period or in the implementation of the land use planning, the urban expansion of Tianhe District aims to meet the shortage of space in the old city area. Its evolution is characterised by the primary stage of urbanisation of Guangzhou.

7.4.2 Comparative study on the change of the rural-urban fringe

The formation and development of the rural-urban fringe is the result of urban development and its essence is the suburbanisation. Under different levels of economies and urbanisation, the suburbanisation possesses various types. In developing countries, suburbanisation takes the form of the urban spreading; whilst in developed countries, the mainstream of the suburbanisation is the suburban spreading. This section, in a broad context, compares the development of the rural-urban fringe in China with that of Western countries, aiming to capture and project the development stages and trends of Tianhe District in future.

In China, because urbanisation has not reached its saturation, the rural population has rapidly poured into the urban area and has exceeded the reasonable population capacity of urban core area. Hence the urban area extended towards the suburban area, developing the residential land, transferring and building new industrial areas.

Comparative analysis (also see, Gu et al., 1995, p136), indicates that many municipalities in China underwent a pattern of the urban spreading from the 1950s to

the 1980s, and became part of municipalities through the formation and development of the rural-urban fringe.

There are two major modes of axis-expansion and outward-expansion (Gu and Ding, 1995). The axis-expansion mainly expands along transport conjunctures, developing industrial corridors, housing corridors, or comprehensive corridors of both. In Beijing, the northwest region expended along the main roads to the universities and college area and developed stores, factories and high-tech enterprises on both sides of the roads (Gu and Ding). In the north Nanjing, a one-kilometre long commercial service building was developed at the north of the railway station, accompanying the building-up of the first-grade road from Beijing to Yangzhou (Cui, 1990). In the north Shahe town of Tianhe District, stores and residential houses were constructed along both sides of the axis of Guangzhou-Shenzhen road, then spread on both sides to link with the original universities and institutes, and gradually an integrated urban landscape was formed to the north of the railway line.

Another mode of urban expansion is outward-expansion, by which urban land-use is spread to the peripheral areas or expands outward in a ring-like or a block-shape fashion (Gu and Ding, 1995). This mode happened when the municipalities faced the housing crisis, but they lacked the powers to build their satellite-towns at the end of the 1970s (Gu and Ding), thus comprehensive development areas were formed in the rural-urban fringe. This is a kind of group-stretch development similar to the Suojincun residential area to the north of the railway station in Nanjing (Cui, 1990), the Anhuili residential area neighbouring the Asian Game Village in north of Beijing (Gu and Ding, 1995), and the residential area around Dongpu Town of the Tianhe District. Another form of the outward-expansion is the regressive expansion (Gu and

Ding, 1995), in which different functions of urban buildings and urban lands were moved to and developed in the rural-urban fringe, and most expanded in the peripheral area, thus the part near the urban area was the first to be urbanised and then spread outward. In view of the land use type, it manifests a regression of replacement process from the traditional rural area, suburban rural area, peripheral urban facilities target area, urban residential area, and finally to the commercial centre. This kind of the group-stretch development with the regressive expansion frequently took place spontaneously. The urban expansions mentioned above, for example, in the north suburban of Beijing, the areas around two railway station of Nanjing, and the centre of Tianhe Dynamism, are all the result of the group-stretch development and of the regressive expansion.

In the developed countries, the development of municipalities generally underwent three periods: from concentration stage, to suburbanisation stage, to de-urbanisation. The urbanisation of the suburban has achieved great progress since the World War II. Because their development levels of economic development and urbanisation were apparently higher than that of developing countries, urban scholars felt that the highly concentrated population in the municipality would bring about environmental and transport problems and have suggested that the satellite towns were built up in the rural-urban fringe out of the municipality so as to avoid the development of the large municipality. This suggestion and implementation were grounded on the basis of economic development and urbanisation in the Western developed countries. This was partly because Western countries had undergone the concentration stage and developed towards the group-expansion of suburbanisation early before the World War II. Many large cities, London, for example, had possessed

more than 1 million people but their attractiveness was lessened by a series of urban diseases, such as urban land shortage, traffic-jams, residential and environmental degradation, etc. At the same time, with the extensive use of cars, modern communication tools and building modern infrastructures of underground and highways, they provided congenial conditions for residents in the rural-urban fringe. In addition, in the fringe, the space is open, the land is cheap and air is cleaner. There are a number of urban facilities, cultural and recreation sites in the fringe, and the difference between rural and urban gradually became smaller. All of these are the essential conditions for the satellite towns.

China began to build satellite towns in the 1960s (Cui, 1990). Generally, most were developed naturally, for example, the satellite towns of Changping and Tongxian of Beijing. The two towns of Shahe and Dongpu of the Tianhe District were planned and developed according to the idea of the satellite town (BLATD, 1995). However, as a result of low economic development level and transport infrastructure, these satellite towns are far behind the satellite functions of Western countries. Some types of the satellite towns were acting as absorbers of the population immigration of the agricultural residents to the urban. Changping and Tongxian in Beijing, for example, did not play a part in dispersing the population and industries of the large cities (Cheng, 1995). Other satellite towns, for example, Tianhe District, were linked with the old city. Actually, the Shahe and Dongpu towns were embraced in the new urban of the Tianhe District. A successful example is the Qinhe Town of Beijing, where a separate industrial town has been developed (Gu and Ding, 1995).

In general, under present economic levels of China, urban expansion mainly takes the form of the outward spreading in the rural-urban fringe. Tianhe District is

running into this stage. The characters and development trends in this stage are dominant in the land use plan for 2010.

7.4.3 Future perspectives

For the purpose of this research, I made a prerequisite assumption in the introduction that the land use planning will be expected to carry out in 2010. Here I discuss further the possibilities of implementing the planning and the future perspectives of Tianhe District.

1. The control and effect of the comprehensive planning of Guangzhou

Tianhe District as a district of Guangzhou municipality. Its development trend is limited and controlled by the comprehensive development and planning of Guangzhou municipality. The administration structure and land administration law of China require that the district of a city should abide by its land use planning based on its upper grade planning. The comprehensive land use planning of Guangzhou determined that its emphasis of urban land use should be placed along the Pearl River and expanded into Huangpu District (BPGM, 1991). The group (Wushan, Shipai and Yuancun) of Tianhe District is a new urban centre of Guangzhou. The commerce, finance and capitals, culture and education, sports and new types of residential area will be developed in the group (CCGM, 1996). The Pearl River Urban Centre and Tianhe high-tech Industrial Area will be established in south of Tianhe Gymnasium. The areas mentioned above are all to the south of the railway line in Tianhe District.

2. The effect of land use policy and law

In recent years the Chinese government has enforced the control of land use and enhanced the function of the land use planning. The new Land Administration Law (1998) will carry out some major reforms in land regulation. A new type of land use regime will replace the one of land grading accounting limit[2], which has been used in China for a long time. At the same time, the comprehensive land use planning and annual plan will be strengthened by which all of the urban construction will be based (CCGM, 1996).

3. Some planning projects are being implemented

Until 1997, when author carried out a field survey, some projects in the land use planning have been roughly completed. For example, the Tianhe Industrial Garden and Tianhe High-Tech Area have been developed and opened. The Pearl River New Town has begun to be put into operation. The three projects mentioned above occupy a large section of land area and this has led to the urbanisation of the neighbouring regions. The east and north of Tianhe District are accelerating the urban sprawl with the combination of group-stretch development and the regressive expansion.

It should be noted that the land use planning is regarded as perfect although the planning is being implemented and applied. As pointed out before, the development stage of Tianhe District looks to be at the stage of Western developed

[2] The land grading accounting limit regime is a sole way by which land users obtain land use right. In the traditional planned period, the higher administration authority sets up the annual land use plan indicators, including the transformation ratio of non-urban land into urban land. These indicators will be assigned in the lower administration authorities. Different authorities have different quotas of land control rights. The land use units should apply for land use rights from the higher land administration department.

countries during World War II. Some urban diseases have come to Tianhe District, for example, the traffic-jams and air pollution, but Tianhe District has played a major role in mitigating the problems of narrow space, land shortage and population growth in the old city area. In addition, the lack of green belts in the planning of the new urban area will degrade the urban life quality. Fortunately, local-planning departments have acknowledged this drawback. From November 1998, Tianhe Land Administration Bureau modified the land use planning, emphasising the construction of a green belt among the urban area and industrial area in the present land use planning[3]. Although some factories, residential and commerce regions have been built in this belt, it is an optimistic sign of the attitude of the modified planning based on the analysis of the planning background and China's land use policy.

7.5 Summary and conclusion

It can be seen from the analysis of this chapter that the development of Tianhe District from a traditional rural area to a rural-urban fringe is a result of the Guangzhou urban sprawl. The location, economic development, population and policy have influenced this evolution process and brought about a deep effect on the change and spatial structure of land use.

[3] According to author's correspondence with Yang Zaigui, the designer of the planning.

CHAPTER 8:

CONCLUSION

It can be clearly seen, through the above studies, that the land use structure of Tianhe District evolved greatly over time and space in the transition from traditional rural area to a rural-urban fringe, and further to be part of the urban area. This chapter provides a conclusion for major findings, points out the role of GIS in the analysis of land use, and puts forward the prospects and directions for future research.

8.1 Major findings

Comparative studies of land use patterns in different periods indicate that land use change of Tianhe District showed the following characteristics:

1. Land use there has passed through three different patterns over the short span of 30 years; that is, the traditional agricultural land use dominated by rural land and woodland; the rural and urban land use in the rural-urban fringe; and urban land use.

2. Viewed in the time order, land use structure of Tianhe District has undertaken a shift from the simple pattern of traditional rural land use structure to the

complex one of the rural-urban land use, and then to the simplified urban land use once again.

3. The force for the formation and growth of the rural-urban fringe mainly comes from the urban expansion of Guangzhou municipality. It first occurred through two forms of expansion, axial development on route ways and outward-spreading, both observed in Tianhe District.

4. The rural-urban fringe as a transition from the traditional rural area to the urban area was influenced by the spatial distance decay principle. Its land use exhibited characteristics with a clear concentric circle pattern successively, i.e., urban land use, mixed land use and rural land use.

5. During the formation and development periods, land use types were transformed dramatically. This transformation was dominated by the transition of rural plots and woodland into urban land, accompanying the complicated interaction between different types of land use. Dramatic socio-economic change had a strong impact on the land use pattern in the rural-urban fringe.

The formation and evolution of land use in the rural-urban fringe were comprehensive results of changing policies, economic development, locational conditions and population expansion. They were the products mutually affected by the physical conditions and socio-economy of Tianhe District in the transition from the planned economy to the market economy of China. Some general reasons for land use change in Tianhe District can be derived as follows:

1. As a suburban area near Guangzhou municipality, Tianhe District had an advantageous location that provided space for urban expansion of Guangzhou, by which population, commerce and industries could move out of the old urban area.

This is a key factor for the formation and development of the rural-urban fringe of Tianhe District.

2. Economic development, industrial structure adjustment and the emergence of rural and township enterprises have led to the restructuring and development of industries in the fringe and also contributed to the development of the rural-urban fringe.

3. The natural population growth of Tianhe District, population expansion of Guangzhou and migrant population have enlarged the needs for residential land. At the same time they generated service industries and increased the needs for urban land. All of these have accelerated the development and evolution of the rural-urban fringe.

4. The existing transport network has helped in shaping the urban sprawl. The formation and development of the fringe first took place along both sides of roads and rivers and gradually spread from these. In turn, the demands of urban expansion furthered development of the transport network.

5. Flat topography provided an advantageous condition for urban construction. The large plain in the south of the District is the best area for urban expansion around Guangzhou Municipality.

6. Land use policy and administration played an effective role in the land use of Tianhe District. At the end of the 1980s, the past policy of free land use was stopped. This accelerated the transformation of the land use pattern. The two occasions of macro-economic policy adjustments, in 1987 and 1992, and the subsequent heat of real estate development, strengthened the transformation of rural land into urban land.

8.2 The role of GIS in this research

GIS, as a powerful spatial analysis tool, plays an important in data collection, database development, data analysis and output. In the area like the rural-urban fringe of Tianhe District where rapid land use change has happened, GIS has helped effective analysis in the land use structure over time and space.

1. Selecting land use information in different periods, a united classification system could be established so that map data could be standardised.

2. Based on the spatial database and through a series of operations, some derivative maps can be created for further analysis.

3. According to the distance from the city centre, a buffer coverage with kilometre belts was developed. Using it to overlay with other maps, some information maps of land use and topography at different kilometre distance were formed, and provided basic data for analysing the land use structure over space.

4. By overlaying land use maps, the characteristics of change in land use patterns over time could be analysed, thus the transformation of land use types could be conveniently detected.

5. By linking the map databases and statistical databases, the factor analysis of land use changes could be carried out effectively and a number of tables and charts could be formed conveniently.

It is not difficult to establish, from this research, that the GIS technique has following characteristics in its application to land use changes.

1. Effectively collecting and managing the data. This research includes land use information from different years and the analysis involves several datasets. If this were carried out by means of traditional methods, the task would be heavy and difficult. GIS provides a number of spatial analysis functions, for example, data collection and overlay. It can be said that this research would be both impossible and difficult if the data operation, analysis and statistics of land use in the kilometre belts and in different years were processed by means of traditional techniques and methods.

2. Strong powerful correction, modification and output functions. As a result of a close link of maps with the database in GIS, it is easy to correct when errors are found. It is also easy to create new maps and output data. At the same time, it is easy to adjust databases when the research needs to make some other classification and adjustment.

3. Rapid map display and table printing. The maps, database and output can be effectively linked together.

8.3 Future research prospects

The main deficit of this research is that it did not quantitatively discuss the spatial impact of transport factor on land use.

This research used the absolute distances from the city centre to analyse the land use changes over space. Theoretically, travel time is a key factor influencing the spatial variations of land use structure. In the practical transport situation of Tianhe District, the circle belts with iso-kilometres were used to imply the transport time. However, they are different in practice and cannot replace each other. Owing to the

lack of available data about travel time in this research, it is left to be studied only in future.

In general, this research applied the spatial analysis functions of GIS and some quantitative methods, targeting analysis on the general characteristics, formation and development of land use in the rural-urban fringe of Tianhe District. This research demonstrated the advantage of application of GIS in the analysis of land use change, and provides a systematic methodology for studies of land use changes in similar regions of China and abroad.

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APPENDICES

Appendix 5-1. Statistics data of socio-economic in Tianhe District

(Part 1)

Year	Total Population	Non-agricultural Population	Gross National Product	Primary Industry	Secondary Industry	Tertiary Industry	Arable area	Private Building
	(person)	(Person)	(Million Yuan)	(Million Yuan)	(Million Yuan)	(Million Yuan)	(ha)	(Sq. Meter)
1984	232423	169652	98.9	35.3	26.3	37.3	2012.6	154525
1985	247811	184541	114.4	40.8	30.4	43.2	1943.9	166655
1986	260371	197445	137.2	46.0	36.0	55.2	1823.0	177288
1987	285785	223935	179.7	60.9	54.5	64.3	1698.1	146237
1988	294761	233630	241.8	67.5	72.9	101.5	1673.3	162789
1989	308793	247276	282.1	86.9	80.7	114.5	1687.6	173692
1990	321103	259417	310.2	88.7	89.4	132.1	1656.5	154445
1991	339300	278977	613.3	86.8	280.9	245.5	1570.7	165441
1992	362700	299918	875.7	115.9	446.1	313.7	1571.4	154474
1993	375906	312865	1694.8	147.1	664.0	883.7	1398.9	144715
1994	399432	337505	2370.0	173.0	930.3	1266.6	1382.8	158894
1995	418120	358440	3358.6	200.0	1032.5	2126.1	1270.5	165462

(Part 2)

Year	Total Population	Non-agricultural Population	Gross National Product	Primary Industry	Secondary Industry	Tertiary Industry	Arable area
	(person)	(Person)	(Million Yuan)	(Million Yuan)	(Million Yuan)	(Million Yuan)	(ha)
1984	232423	169652	98.9	35.3	26.3	37.3	2012.6
1985	247811	184541	114.4	40.8	30.4	43.2	1943.9
1986	260371	197445	137.2	46.0	36.0	55.2	1823.0
1987	285785	223935	179.7	60.9	54.5	64.3	1698.1
1988	294761	233630	241.8	67.5	72.9	101.5	1673.3
1989	308793	247276	282.1	86.9	80.7	114.5	1687.6
1990	321103	259417	310.2	88.7	89.4	132.1	1656.5
1991	339300	278977	613.3	86.8	280.9	245.5	1570.7
1992	362700	299918	875.7	115.9	446.1	313.7	1571.4
1993	375906	312865	1694.8	147.1	664.0	883.7	1398.9
1994	399432	337505	2370.0	173.0	930.3	1266.6	1382.8
1995	418120	358440	3358.6	200.0	1032.5	2126.1	1270.5

Appendix 5-2. Coverage used in this research

Theme	Type	Coverage Name	Note (Map Section Number)
original input			
control coverage	Tic	Tic	
contour map	Arc/Point	DAAA	F-49-35-22
contour map	Arc/Point	DAAB	F-49-35-23
contour map	Arc/Point	DAAC	F-49-35-29
contour map	Arc/Point	DAAD	F-49-35-30
contour map	Arc/Point	DAAE	F-49-35-31
contour map	Arc/Point	DAAF	F-49-35-32
contour map	Arc/Point	DAAG	F-49-35-37
contour map	Arc/Point	DAAH	F-49-35-38
contour map	Arc/Point	DAAI	F-49-35-39
contour map	Arc/Point	DAAJ	F-49-35-40
contour map	Arc/Point	DAAK	F-49-35-45
contour map	Arc/Point	DAAL	F-49-35-46
contour map	Arc/Point	DAAM	F-49-35-47
land use map in 1973	Arc/Poly	L73AAA	F-49-35-22
land use map in 1973	Arc/Poly	L73AAB	F-49-35-23
land use map in 1973	Arc/Poly	L73AAC	F-49-35-29
land use map in 1973	Arc/Poly	L73AAD	F-49-35-30
land use map in 1973	Arc/Poly	L73AAE	F-49-35-31
land use map in 1973	Arc/Poly	L73AAF	F-49-35-32
land use map in 1973	Arc/Poly	L73AAG	F-49-35-37
land use map in 1973	Arc/Poly	L73AAH	F-49-35-38
land use map in 1973	Arc/Poly	L73AAI	F-49-35-39
land use map in 1973	Arc/Poly	L73AAJ	F-49-35-40
land use map in 1973	Arc/Poly	L72AAK	F-49-35-45
land use map in 1973	Arc/Poly	L73AAL	F-49-35-46
land use map in 1973	Arc/Poly	L73AAM	F-49-35-47
land use map in 1993	Arc/Poly	L93AAA	
land use map in 1993	Arc/Poly	L93AAB	
land use map in 1993	Arc/Poly	L93AAC	
land use map in 1993	Arc/Poly	L93AAD	
land use map in 1993	Arc/Poly	L93AAE	
land use map in 1993	Arc/Poly	L93AAF	
land use plan map	Arc/Poly	PLAN2010	
conjuncted maps.....		....	
land use map in 1973	Arc/Poly.	LAND73	
land use map in 1993	Arc/Poly	LAND93	
contour map	Arc/point	CONTOUR	

Appendix 6-1. Land use structures

	land use type	1973	%	1993	%	2010	%
51	urban	94.6	0.6	2336.7	15.7	7106.3	47.6
52	rural-residential	728.5	4.9	953.2	6.4	0.0	0.0
53	industrial	1087.9	7.3	2620.6	17.6	3725.9	25.0
60	transport	98.0	0.7	445.44	3.0	1155.3	7.7
10	arable land	5549.3	37.2	2463.7	16.5	82.8	0.6
20	orchard	790.7	5.3	1338.5	9.0	89.2	0.6
30	wood	5628.3	37.7	3576.86	24.0	2401.2	16.1
70	water body	936.8	6.3	962.4	6.4	368.8	2.5
80	un-used	15.3	0.1	232.1	1.6	0.0	0.0
	Total	14929.4	100.0	14929.4	100.0	14929.5	100.0

Appendix 6-2. Land use type variations with distance in 1973 (Value)

Unit: ha

Distance	Land use type									Total
	51	52	53	60	10	20	30	70	80	
2	0.0	17.0	0.0	0.4	19.8	0.0	20.1	0.7	0.0	58.0
3	0.0	11.8	7.9	3.1	3.9	0.0	213.3	27.0	0.0	267.1
4	23.8	2.9	13.0	2.7	0.1	0.0	143.0	5.5	0.0	191.0
5	70.7	11.8	79.8	7.6	211.5	1.9	49.2	34.8	1.0	468.3
6	0.0	85.2	84.4	8.0	299.0	56.1	38.8	79.4	1.1	652.2
7	0.0	73.3	131.5	8.4	255.6	64.3	159.7	73.7	1.5	767.9
8	0.0	114.6	119.9	6.2	256.4	25.6	210.6	52.0	3.1	788.3
9	0.0	99.8	229.5	5.4	224.8	7.7	205.7	66.9	2.2	841.9
10	0.0	77.9	73.9	9.2	257.7	35.6	437.8	54.2	4.3	950.6
11	0.0	19.3	42.7	4.7	449.3	58.4	384.4	86.0	0.0	1044.7
12	0.0	16.8	92.8	9.1	585.7	49.0	352.6	69.8	0.0	1175.8
13	0.0	70.2	88.7	11.2	491.8	39.3	546.5	108.0	1.6	1357.2
14	0.0	35.1	32.5	8.1	899.7	13.2	458.8	82.1	0.0	1529.4
15	0.0	56.5	45.6	6.8	746.7	119.1	539.4	76.3	0.0	1590.3
16	0.0	21.4	27.1	5.2	462.7	135.2	742.0	67.7	0.0	1461.3
17	0.0	12.0	18.8	1.9	240.2	91.2	651.8	39.0	0.0	1054.9
18	0.0	2.9	0.0	0.0	132.9	94.1	397.4	13.7	0.5	641.4
19	0.0	0.0	0.0	0.0	11.6	0.0	77.2	0.1	0.0	88.9
Total	94.6	728.5	1087.9	98.0	5549.3	790.7	5628.3	936.8	15.3	14929.4

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-3. Land use type variations with distance in 1973 (Percentage)

Unit: %

Distance	Land use type									Total
	51	52	53	60	10	20	30	70	80	
2	0.0	29.3	0.0	0.7	34.2	0.0	34.6	1.1	0.0	100
3	0.0	4.4	3.0	1.2	1.5	0.0	79.9	10.1	0.0	100
4	12.5	1.5	6.8	1.4	0.0	0.0	74.9	2.9	0.0	100
5	15.1	2.5	17.0	1.6	45.2	0.4	10.5	7.4	0.2	100
6	0.0	13.1	12.9	1.2	45.8	8.6	5.9	12.2	0.2	100
7	0.0	9.5	17.1	1.1	33.3	8.4	20.8	9.6	0.2	100
8	0.0	14.5	15.2	0.8	32.5	3.3	26.7	6.6	0.4	100
9	0.0	11.9	27.3	0.6	26.7	0.9	24.4	7.9	0.3	100
10	0.0	8.2	7.8	1.0	27.1	3.7	46.1	5.7	0.5	100
11	0.0	1.8	4.1	0.4	43.0	5.6	36.8	8.2	0.0	100
12	0.0	1.4	7.9	0.8	49.8	4.2	30.0	5.9	0.0	100
13	0.0	5.2	6.5	0.8	36.2	2.9	40.3	8.0	0.1	100
14	0.0	2.3	2.1	0.5	58.8	0.9	30.0	5.4	0.0	100
15	0.0	3.6	2.9	0.4	46.9	7.5	33.9	4.8	0.0	100
16	0.0	1.5	1.9	0.4	31.7	9.3	50.8	4.6	0.0	100
17	0.0	1.1	1.8	0.2	22.8	8.6	61.8	3.7	0.0	100
18	0.0	1.1	1.8	0.2	22.8	8.6	61.8	3.7	0.0	100
19	0.0	0.5	0.0	0.0	20.7	14.7	62.0	2.1	0.1	100

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-4. Land use type variations with distance in 1993 (Value)

Unit: ha

Distance	Land use type									Total
	51	52	53	60	10	20	30	70	80	
2	19.3	9.2	20.7	2.6	0.0	0.2	5.9	0.0	0.0	58.0
3	36.6	5.7	54.7	5.2	0.8	8.2	132.9	23.0	0.0	267.1
4	54.0	15.3	19.2	9.7	0.2	4.5	85.3	2.8	0.0	191.0
5	210.1	34.3	86.2	54.8	47.9	5.9	7.7	21.3	0.0	468.3
6	344.1	25.8	104.5	50.5	36.6	39.4	3.3	48.1	0.0	652.2
7	366.0	55.4	90.0	39.2	75.7	41.1	31.8	67.1	1.6	767.9
8	402.0	50.4	105.3	26.8	88.0	24.0	31.9	56.9	3.1	788.3
9	469.4	26.2	103.0	23.2	97.7	6.5	42.1	73.5	0.4	841.9
10	275.7	80.0	200.2	27.1	123.4	33.2	113.1	78.9	18.9	950.7
11	83.3	48.9	270.9	30.7	155.4	49.3	246.9	121.2	38.1	1044.7
12	51.1	88.7	273.2	33.7	260.2	50.6	323.1	79.4	16.0	1175.9
13	11.2	119.2	332.0	49.0	269.4	94.7	365.1	85.7	30.9	1357.1
14	13.9	64.3	339.6	43.5	472.5	127.8	357.8	94.4	15.3	1529.1
15	0.0	186.2	244.8	17.5	406.8	232.7	396.7	88.8	17.2	1590.6
16	0.0	77.6	206.8	17.8	240.8	228.3	592.6	72.6	24.6	1461.2
17	0.0	52.1	138.8	7.9	101.5	225.5	449.1	34.4	45.7	1054.9
18	0.0	13.9	27.5	6.2	79.8	153.4	328.1	14.2	18.3	641.4
19	0.0	0.0	3.2	0.0	7.0	13.2	63.5	0.1	1.9	89.0
Total	2336.7	953.2	2620.6	445.4	2463.7	1338.5	3576.9	962.4	232.1	14929.4

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-5. Land use type variations with distance in 1993 (Percentage)

Unit: %

Distance	Land use type									Total
	51	52	53	60	10	20	30	70	80	
2	33.2	15.9	35.7	4.6	0.0	0.4	10.2	0.0	0.0	100
3	13.7	2.1	20.5	1.9	0.3	3.1	49.7	8.6	0.0	100
4	28.3	8.0	10.1	5.1	0.1	2.4	44.7	1.5	0.0	100
5	44.9	7.3	18.4	11.7	10.2	1.3	1.6	4.6	0.0	100
6	52.8	4.0	16.0	7.7	5.6	6.0	0.5	7.4	0.0	100
7	47.7	7.2	11.7	5.1	9.9	5.3	4.1	8.7	0.2	100
8	51.0	6.4	13.4	3.4	11.2	3.0	4.1	7.2	0.4	100
9	55.8	3.1	12.2	2.8	11.6	0.8	5.0	8.7	0.0	100
10	29.0	8.4	21.1	2.9	13.0	3.5	11.9	8.3	2.0	100
11	8.0	4.7	25.9	2.9	14.9	4.7	23.6	11.6	3.6	100
12	4.3	7.5	23.2	2.9	22.1	4.3	27.5	6.8	1.4	100
13	0.8	8.8	24.5	3.6	19.8	7.0	26.9	6.3	2.3	100
14	0.9	4.2	22.2	2.8	30.9	8.4	23.4	6.2	1.0	100
15	0.0	11.7	15.4	1.1	25.6	14.6	24.9	5.6	1.1	100
16	0.0	5.3	14.2	1.2	16.5	15.6	40.6	5.0	1.7	100
17	0.0	4.9	13.2	0.7	9.6	21.4	42.6	3.3	4.3	100
18	0.0	2.2	4.3	1.0	12.4	23.9	51.2	2.2	2.9	100
19	0.0	0.0	3.6	0.0	7.9	14.8	71.4	0.1	2.2	100

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-6 Land use type variation with distance in 2010 (Value)

Unit: ha

Distance	Land use type									Total
	51	52	53	60	10	20	30	70	80	
2	26.0	0.0	0.0	6.3	0.0	0.0	25.7	0.0	0.0	58.0
3	32.2	0.0	0.0	15.4	0.0	0.0	202.7	16.8	0.0	267.1
4	79.3	0.0	0.0	17.1	0.0	0.0	93.3	1.4	0.0	191.1
5	403.1	0.0	0.0	61.0	0.0	0.0	0.0	4.3	0.0	468.3
6	550.0	0.0	0.0	80.0	0.0	0.0	0.0	22.1	0.0	652.1
7	599.5	0.0	40.7	66.3	0.0	0.0	37.3	24.2	0.0	768.0
8	616.5	0.0	76.1	56.6	0.0	0.0	16.2	23.0	0.0	788.3
9	593.4	0.0	169.2	55.0	0.0	0.0	0.0	24.3	0.0	841.9
10	410.7	0.0	388.7	59.2	0.0	0.0	63.9	28.3	0.0	950.7
11	384.6	0.0	495.4	81.6	0.0	0.0	47.2	35.7	0.0	1044.6
12	108.1	0.0	704.5	94.8	17.5	0.0	217.5	33.5	0.0	1175.8
13	314.2	0.0	585.0	90.7	33.8	0.0	300.4	33.2	0.0	1357.2
14	700.1	0.0	302.5	132.4	28.4	0.0	311.7	54.3	0.0	1529.4
15	888.1	0.0	286.0	144.3	3.1	46.6	199.1	23.1	0.0	1590.4
16	727.8	0.0	199.1	98.8	0.0	35.4	369.8	30.4	0.0	1461.2
17	411.0	0.0	281.3	51.7	0.0	7.2	289.6	14.2	0.0	1054.9
18	224.3	0.0	194.4	43.9	0.0	0.0	178.9	0.0	0.0	641.4
19	37.4	0.0	3.2	0.5	0.0	0.0	47.8	0.0	0.0	88.8
Total	7106.3	0.0	3725.9	1155.3	82.8	89.2	2401.2	368.8	0.0	14929.4

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-7. Land use type variations with distance in 2010 (Percentage)

Unit: %

Distance	Land use type									Total
	51	52	53	60	10	20	30	70	80	
2	44.8	0.0	0.0	10.8	0.0	0.0	44.4	0.0	0.0	100
3	12.1	0.0	0.0	5.8	0.0	0.0	75.9	6.3	0.0	100
4	41.5	0.0	0.0	8.9	0.0	0.0	48.9	0.7	0.0	100
5	86.1	0.0	0.0	13.0	0.0	0.0	0.0	0.9	0.0	100
6	84.3	0.0	0.0	12.3	0.0	0.0	0.0	3.4	0.0	100
7	78.1	0.0	5.3	8.6	0.0	0.0	4.9	3.1	0.0	100
8	78.2	0.0	9.7	7.2	0.0	0.0	2.1	2.9	0.0	100
9	70.5	0.0	20.1	6.5	0.0	0.0	0.0	2.9	0.0	100
10	43.2	0.0	40.9	6.2	0.0	0.0	6.7	3.0	0.0	100
11	36.8	0.0	47.4	7.8	0.0	0.0	4.5	3.4	0.0	100
12	9.2	0.0	59.9	8.1	1.5	0.0	18.5	2.8	0.0	100
13	23.1	0.0	43.1	6.7	2.5	0.0	22.1	2.4	0.0	100
14	45.8	0.0	19.8	8.7	1.9	0.0	20.4	3.5	0.0	100
15	55.8	0.0	18.0	9.1	0.2	2.9	12.5	1.5	0.0	100
16	49.8	0.0	13.6	6.8	0.0	2.4	25.3	2.1	0.0	100
17	39.0	0.0	26.7	4.9	0.0	0.7	27.4	1.3	0.0	100
18	35.0	0.0	30.3	6.8	0.0	0.0	27.9	0.0	0.0	100
19	42.1	0.0	3.6	0.5	0.0	0.0	53.8	0.0	0.0	100

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-8. Slope variations with distance

Unit: ha

Distance	Slope degree								Total	
	0-2	%	2-6	%	6-15	%	>15	%	Total	%
2	36.0	62.0	4.8	8.2	9.0	15.5	8.3	14.3	55.3	100
3	81.8	30.6	57.4	21.5	79.5	29.8	48.5	18.1	197.4	100
4	93.1	48.8	16.5	8.6	57.1	29.9	24.3	12.7	132.6	100
5	439.0	93.7	13.2	2.8	8.3	1.8	7.8	1.7	22.3	100
6	598.4	91.8	36.3	5.6	13.4	2.1	4.1	0.6	25.7	100
7	611.4	79.6	80.0	10.4	54.2	7.1	22.3	2.9	96.8	100
8	591.3	75.0	107.1	13.6	80.2	10.2	9.8	1.2	115.0	100
9	584.1	69.4	133.1	15.8	111.9	13.3	12.7	1.5	155.3	100
10	607.0	63.8	195.3	20.5	143.2	15.1	5.2	0.5	184.5	100
11	733.1	70.2	120.0	11.5	126.7	12.1	65.0	6.2	221.5	100
12	879.3	74.8	87.0	7.4	120.5	10.3	88.9	7.6	234.7	100
13	917.2	67.6	87.2	6.4	124.4	9.2	228.4	16.8	385.2	100
14	1078.5	70.5	126.3	8.3	121.5	7.9	203.2	13.3	354.2	100
15	1021.5	64.2	155.4	9.8	231.4	14.6	182.0	11.4	449.2	100
16	686.7	47.0	148.1	10.1	265.8	18.2	360.6	24.7	679.4	100
17	448.7	42.5	117.1	11.1	216.4	20.5	272.8	25.9	546.6	100
18	277.9	43.3	56.0	8.7	163.9	25.5	143.7	22.4	364.3	100
19	29.5	33.2	3.9	4.4	22.5	25.3	33.0	37.1	122.3	100
Total	9714.5		1544.7		1949.8		1720.4		4342.2	

Appendix 6-9. Land use variations with slope in 1973 (value)

Unit: ha

Slope	Land use type									Total
	10	20	30	51	52	53	60	70	80	
0-2	87.1	575.1	813.6	77.9	4986.2	517.4	1782.0	859.9	15.3	9714.5
2-6	3.6	104.7	141.6	11.5	378.2	135.6	704.2	65.2	0	1544.7
6-15	3.3	43.4	114.2	7.9	172.9	135.0	1464.2	9.0	0	1949.8
>15	0.5	5.3	18.6	0.7	12.1	2.6	1677.8	2.8	0	1720.4
Total	94.6	728.5	1088.0	98.0	5549.3	790.7	5628.3	936.8	15.3	14929.4

Note:
10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-10. Land use variations with slope in 1973 (percentage)

Unit: %

Slope	Land use type								
	10	20	30	51	52	53	60	70	80
0-2	92.1	78.9	74.8	79.5	89.9	65.4	31.7	91.8	100.0
2-6	3.9	14.4	13.0	11.7	6.8	17.1	12.5	7.0	0.0
6-15	3.5	6.0	10.5	8.0	3.1	17.1	26.0	1.0	0.0
>15	0.6	0.7	1.7	0.7	0.2	0.3	29.8	0.3	0.0
Total	100	100	100	100	100	100	100	100	100

Note:
10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-11. Land use variations with slope in 1993 (value)

Unit: ha

Slope	Land use type									Total
	10	20	30	51	52	53	60	70	80	
0-2	1690.6	747.6	1860.8	387.0	2304.0	805.4	968.4	866.3	84.5	9714.5
2-6	348.5	114.6	342.3	35.2	123.3	201.8	271.0	71.2	36.6	1544.7
6-15	268.3	83.4	328.0	21.7	33.5	278.6	840.8	21.4	74.3	1949.8
>15	29.3	7.6	89.5	1.6	2.8	52.7	1496.7	3.6	36.7	1720.4
Total	2336.7	953.2	2620.6	445.5	2463.6	1338.5	3576.9	962.4	232.0	14929.4

Note:
10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-12. Land use variations with slope in 1993 (percentage)

Unit: %

Slope	Land use type								
	10	20	30	51	52	53	60	70	80
0-2	72.3	71.0	71.0	93.5	93.5	60.2	27.1	90.0	36.4
2-6	14.9	13.1	13.1	5.0	5.0	15.1	7.6	7.4	15.8
6-15	11.5	12.5	12.5	1.4	1.4	20.8	23.5	2.2	32.0
>15	1.3	3.4	3.4	0.1	0.1	3.9	41.8	0.4	15.8
Total	100	100	100	100	100	100	100	100	100

Note:
10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-13. Land use variations with slope in 2010 (value)

Unit: ha

Slope	Land use type									Total
	10	20	30	51	52	53	60	70	80	
0-2	5365.5	0.0	2265.2	871.3	66.4	29.8	779.3	337.1	0.0	9714.5
2-6	820.1	0.0	451.0	110.9	13.4	8.0	127.7	13.6	0.0	1544.7
6-15	946.2	0.0	475.8	126.8	27.8	26.4	328.8	18.0	0.0	1949.8
>15	326.3	0.0	142.6	46.2	26.1	25.0	1137.0	17.5	0.0	1720.4
Total	7458.0	0.0	3334.6	1155.1	133.7	89.2	2372.8	386.2	0.0	14929.4

Note:
10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 6-14. Land use variations with slope in 1993 (percentage)

Unit: %

Slope	Land use type								
	10	20	30	51	52	53	60	70	80
0-2	71.9	0.0	67.9	75.4	49.7	33.4	32.8	87.3	0.0
2-6	11.0	0.0	13.5	9.6	10.0	9.0	5.4	3.5	0.0
6-15	12.7	0.0	14.3	11.0	20.8	29.6	13.9	4.7	0.0
>15	4.4	0.0	4.3	4.0	19.5	28.0	47.9	4.5	0.0
Total	100		100	100	100	100	100	100	100

Note:
10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 7-1. Calculation table of the diversity index of land use structure in 1973

Distance	$p_i \ln p_i$									Index (H)
	51	52	53	60	10	20	30	70	80	
2	0.00	-0.36	0.00	-0.04	-0.37	0.00	-0.37	-0.05	0.00	1.18
3	0.00	-0.14	-0.10	-0.05	-0.06	0.00	-0.18	-0.23	0.00	0.77
4	-0.26	-0.06	-0.18	-0.06	0.00	0.00	-0.22	-0.10	0.00	0.89
5	-0.29	-0.09	-0.30	-0.07	-0.36	-0.02	-0.24	-0.19	-0.01	1.57
6	0.00	-0.27	-0.26	-0.05	-0.36	-0.21	-0.17	-0.26	-0.01	1.59
7	0.00	-0.22	-0.30	-0.05	-0.37	-0.21	-0.33	-0.22	-0.01	1.71
8	0.00	-0.28	-0.29	-0.04	-0.37	-0.11	-0.35	-0.18	-0.02	1.64
9	0.00	-0.25	-0.35	-0.03	-0.35	-0.04	-0.34	-0.20	-0.02	1.60
10	0.00	-0.21	-0.20	-0.04	-0.35	-0.12	-0.36	-0.16	-0.02	1.47
11	0.00	-0.07	-0.13	-0.02	-0.36	-0.16	-0.37	-0.21	0.00	1.33
12	0.00	-0.06	-0.20	-0.04	-0.35	-0.13	-0.36	-0.17	0.00	1.31
13	0.00	-0.15	-0.18	-0.04	-0.37	-0.10	-0.37	-0.20	-0.01	1.42
14	0.00	-0.09	-0.08	-0.03	-0.31	-0.04	-0.36	-0.16	0.00	1.07
15	0.00	-0.12	-0.10	-0.02	-0.35	-0.19	-0.37	-0.15	0.00	1.31
16	0.00	-0.06	-0.07	-0.02	-0.36	-0.22	-0.34	-0.14	0.00	1.23
17	0.00	-0.05	-0.07	-0.01	-0.34	-0.21	-0.30	-0.12	0.00	1.10
18	0.00	-0.02	0.00	0.00	-0.33	-0.28	-0.30	-0.08	-0.01	1.02
19	0.00	0.00	0.00	0.00	-0.27	0.00	-0.12	-0.01	0.00	0.40
Total	-0.03	-0.15	-0.19	-0.03	-0.37	-0.16	-0.37	-0.17	-0.01	1.48

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 7-2. Calculation table of the diversity index of land use structure in 1993

Distance	$p_i \ln p_i$									Index (H)
	51	52	53	60	10	20	30	70	80	
2	-0.37	-0.29	-0.37	-0.14	0.00	-0.02	-0.23	0.00	0.00	1.42
3	-0.27	-0.08	-0.32	-0.08	-0.02	-0.11	-0.35	-0.21	0.00	1.44
4	-0.36	-0.20	-0.23	-0.15	-0.01	-0.09	-0.36	-0.06	0.00	1.46
5	-0.36	-0.19	-0.31	-0.25	-0.23	-0.06	-0.07	-0.14	0.00	1.61
6	-0.34	-0.13	-0.29	-0.20	-0.16	-0.17	-0.03	-0.19	0.00	1.51
7	-0.35	-0.19	-0.25	-0.15	-0.23	-0.16	-0.13	-0.21	-0.01	1.69
8	-0.34	-0.18	-0.27	-0.11	-0.24	-0.11	-0.13	-0.19	-0.02	1.60
9	-0.33	-0.11	-0.26	-0.10	-0.25	-0.04	-0.15	-0.21	0.00	1.44
10	-0.36	-0.21	-0.33	-0.10	-0.27	-0.12	-0.25	-0.21	-0.08	1.92
11	-0.20	-0.14	-0.35	-0.10	-0.28	-0.14	-0.34	-0.25	-0.12	1.94
12	-0.14	-0.19	-0.34	-0.10	-0.33	-0.14	-0.35	-0.18	-0.06	1.84
13	-0.04	-0.21	-0.34	-0.12	-0.32	-0.19	-0.35	-0.17	-0.09	1.84
14	-0.04	-0.13	-0.33	-0.10	-0.36	-0.21	-0.34	-0.17	-0.05	1.74
15	0.00	-0.25	-0.29	-0.05	-0.35	-0.28	-0.35	-0.16	-0.05	1.78
16	0.00	-0.16	-0.28	-0.05	-0.30	-0.29	-0.37	-0.15	-0.07	1.66
17	0.00	-0.15	-0.27	-0.04	-0.23	-0.33	-0.36	-0.11	-0.14	1.62
18	0.00	-0.08	-0.14	-0.04	-0.26	-0.34	-0.34	-0.08	-0.10	1.39
19	0.00	0.00	-0.12	0.00	-0.20	-0.28	-0.24	-0.01	-0.08	0.94
Total	-0.29	-0.18	-0.31	-0.10	-0.30	-0.22	-0.34	-0.18	-0.06	1.97

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 7-3. Calculation table of the diversity index of land use structure in 2010

Distance	$p_i \ln p_i$									Index (H)
	51	52	53	60	10	20	30	70	80	
2	-0.36	0.00	0.00	-0.24	0.00	0.00	-0.36	0.00	0.00	0.96
3	-0.36	0.00	0.00	-0.16	0.00	0.00	-0.21	-0.17	0.00	0.91
4	-0.37	0.00	0.00	-0.22	0.00	0.00	-0.35	-0.04	0.00	0.97
5	-0.13	0.00	0.00	-0.27	0.00	0.00	0.00	-0.04	0.00	0.44
6	-0.14	0.00	0.00	-0.26	0.00	0.00	0.00	-0.11	0.00	0.52
7	-0.19	0.00	-0.16	-0.21	0.00	0.00	-0.15	-0.11	0.00	0.82
8	-0.19	0.00	-0.23	-0.19	0.00	0.00	-0.08	-0.10	0.00	0.79
9	-0.25	0.00	-0.32	-0.18	0.00	0.00	0.00	-0.10	0.00	0.85
10	-0.34	0.00	-0.36	-0.17	0.00	0.00	-0.21	-0.10	0.00	1.19
11	-0.36	0.00	-0.37	-0.20	0.00	0.00	-0.19	-0.12	0.00	1.24
12	-0.33	0.00	-0.35	-0.20	-0.06	0.00	-0.31	-0.10	0.00	1.36
13	-0.35	0.00	-0.37	-0.18	-0.14	0.00	-0.32	-0.09	0.00	1.45
14	-0.36	0.00	-0.32	-0.21	-0.11	0.00	-0.30	-0.14	0.00	1.44
15	-0.33	0.00	-0.31	-0.22	-0.01	-0.10	-0.26	-0.07	0.00	1.29
16	-0.35	0.00	-0.27	-0.18	0.00	-0.09	-0.35	-0.08	0.00	1.32
17	-0.37	0.00	-0.35	-0.15	0.00	-0.03	-0.35	-0.06	0.00	1.31
18	-0.37	0.00	-0.36	-0.18	0.00	0.00	-0.36	0.00	0.00	1.27
19	-0.36	0.00	-0.12	-0.03	0.00	0.00	-0.33	0.00	0.00	0.85
Total	-0.35	0.00	-0.33	-0.20	-0.04	-0.03	-0.29	-0.09	0.00	1.34

Note:

10. arable land
20. orchard
30. woodland
51. urban
52. rural residential
53. industries
60. transport
70. water body
80. unused land

Appendix 7-4. Land use type variations with Districts in Guangzhou (value)

Unit: ha

Land use type	Districts								Total
	Dongshan	Yuexiu	Liwan	Tianghe	Haizhu	Fangcun	Huangpu	Baiyun	
urban	0.4	0.0	0.0	2336.7	2444.6	1864.2	2897.3	37296.9	46840.2
rural res.	3.6	0.0	0.0	953.2	1857.5	162.9	2895.6	9605.8	15478.4
industrial	0.0	0.0	0.0	2620.6	4302.1	2027.1	5792.8	46902.7	61645.4
transport	1218.0	620.1	802.0	445.4	1298.2	378.6	274.5	1326.0	6362.7
arable	0.0	0.0	0.0	2463.7	561.4	415.9	489.2	5254.9	9185.0
orchard	1218.0	620.1	802.0	1338.5	1859.6	794.4	763.7	6580.9	13977.1
wood	72.6	51.5	84.0	3576.9	48.9	61.1	396.0	686.3	4977.3
water	134.9	18.7	115.7	962.4	1957.0	783.6	2007.2	5297.1	11276.6
un-used	0.0	0.0	0.0	232.1	1.2	2.0	193.2	2926.0	3354.5
Total	2647.4	1310.4	1803.7	14929.4	14330.6	6489.7	15709.4	115876.7	173097.3

Appendix 7-5. Land use type variations with Districts in Guangzhou (Percentage)

Unit (%)

Land use type	Districts								Total
	Dongshan	Yuexiu	Liwan	Tianghe	Haizhu	Fangcun	Huangpu	Baiyun	
urban	0.0	0.0	0.0	15.7	17.1	28.7	18.4	32.2	27.1
rural res.	0.1	0.0	0.0	6.4	13.0	2.5	18.4	8.3	8.9
industrial	0.0	0.0	0.0	17.6	30.0	31.2	36.9	40.5	35.6
transport	46.0	47.3	44.5	3.0	9.1	5.8	1.7	1.1	3.7
arable	0.0	0.0	0.0	16.5	3.9	6.4	3.1	4.5	5.3
orchard	46.0	47.3	44.5	9.0	13.0	12.2	4.9	5.7	8.1
wood	2.7	3.9	4.7	24.0	0.3	0.9	2.5	0.6	2.9
water	5.1	1.4	6.4	6.4	13.7	12.1	12.8	4.6	6.5
un-used	0.0	0.0	0.0	1.6	0.0	0.0	1.2	2.5	1.9
Total	100	100	100	100	100	100	100	100	100

Appendix 7-6. Economic and population in the Guangzhou during 1973-1992

Year	GNP	Population
	Billion Yuan	Million
1973	3.4	1.9
1974	4.2	2.0
1975	5.6	1.9
1976	8.3	2.0
1977	7.3	2.0
1978	7.3	2.1
1979	7.4	2.2
1980	10.0	2.3
1981	13.6	2.3
1982	21.0	2.4
1983	22.9	2.4
1984	29.6	2.5
1985	43.6	2.6
1986	52.5	2.6
1987	58.4	2.7
1988	90.2	2.8
1989	93.3	2.9
1990	90.6	2.9
1991	103.7	3.0
1992	188.1	3.0