Modelling the spatial pattern of urban fringe

Case study Hongshan, Wuhan

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by

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Abstract

Urban fringe is the foreland in the process of "urban sprawl", especially in developing countries e.g. China. The rapid land use changes in this transitional and semi-urban system often puzzled urban researchers.

Recently, a spatially explicit model named CLUE (Conversion of Land Use and its Effects) is widely applied to explore the spatial and temporal dynamics of land use. It provides a useful tool to understand the complex and dynamic spatial pattern of urban fringe better.

CLUE model is designed to obtain insights into the complexity of the land-use situation as well as to explore and quantify near-future pathways of land-use development. The approach used in the CLUE modelling framework to allocate land-use changes attempts to account for the entire system of complex interactions between historic and present land use, socio-economic conditions and biophysical constraints. Interactions between land-use elements and the scale dependency of both the structure and function of the land-use pattern are explicitly addressed as well.

In this research, CLUE model is developed as CLUE-HS model to understand the land use pattern of Hongshan District, the fringe of Wuhan city, China. Based on the literature and interview with local planners, possible factors underlying every kind of land use type were identified with the help of DPSIR model. And the significant factors influencing the land use change in Hongshan District were found out through the logistic regression model.

The land use patterns of Hongshan District from 1996 to 2010 are simulated and the possible scenarios are generated for different alternatives. However the results still need care to interpret because of the limited data.

Based on the results of this study, the land use pattern of Hongshan District is presented explicitly. CLUE model is proved a good tool to understand the spatial pattern of urban fringe.

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1. Introduction

1.1. Background

In the past twenty years, China has experienced a tremendous economic growth. This growth does not only express itself in an increase in the urban population, but also in an expansion of the urban area. The expansion indicates a transformation of agricultural land use to construction of urban fabrics including residential, industrial and infrastructure development. The processes of change are most obvious in the vicinity of urban zones. Urban zones are not only attracting rural population because of their supply of income opportunities, but also have a rather strong influence on the socio-economic activities in the zone surrounding them. Because of these urban influences, not only a growing part of the rural population living in those areas is no longer directly employed in the tradition rural activities, also a shift in the land use is taking place. Thus urban fringe, a transitional, integrated, semi-urban zone consisting of diverse land uses comes forth.

Unfortunately coinciding with the rapid development of this transition area, a lot of socio-economic problems emerge (e.g. land use fractal, infrastructure services lagging, unauthorized buildings, environment deteriorating….). In this sense, urban fringe is a so-called “problem area”. The transition area with flux characters also puzzles urban researchers. Many questions arise in their mind such as what is urban fringe? How dose the fringe development? Which driving forces are underlying the urban fringe development? What are the essential factors? How these factors interact with each other?

Fringe urbanization has raised new challenges for urbanization theory and development policy, many efforts and methods have been done to understand the urban fringe’s development process. But most of them seem to be at the descriptive rather than the predictive level (Cuo 1990; Gu 1993; Wei 2000). Many relations found are straightforward and in correspondence with our understanding of land use. However, the systematic analysis allows us to define the relative importance of the different explanatory factors and quantifies the regional differences. Although it is well understood that correlations are no substitute for mechanistic understanding of relationships, correlations can play an invaluable role in suggesting mechanisms for further investigation (Levin, 1993). Considering of the complex and dynamic character of urban fringe, modelling is the unique tool to understand its process thoroughly. Although models such as CA are highly idealized and artificial, they can provide a suggestive way of exploring actual as well as optimal patterns and plans (Batty, 1997).

Recently, a spatially explicit model named CLUE (Conversion of Land Use and its Effects) is widely applied to explore the spatial and temporal dynamics of land use (Verburg 2000;Kok and Winogard, 2001; de Koning, 1999).

The CLUE modelling framework is designed to simulate land use change using empirically quantified relations between land use and its driving factors in combination with dynamic modelling of competition between land use types. It is a dynamic, multi-scale, real-time, and spatially detailed land use model. With the high explanatory power, the logistic regression model indicates that we are able to capture the key factors explaining the land-use distribution. The CLUE model provides a unique tool to obtain insights into the pathways of urban fringe's land use development.

1.2. Research problem

Urban fringe is the foreland in the process of "urban sprawl", especially in developing countries e.g. China, India. It is the so-called most sensitive area for its development is affected not only by urban centre but also rural. In urban fringe land use changes so quickly that relevant urban planning and policy cannot accommodate with its dynamic and complex development.

Consequently, Many problems emerge in this area with the trend of metropolis' expansion .To solve these problems, it is fundamental to understand how the urban fringe works. It has assumed great topical importance but sadly remained a neglected area in urban research. In this field most of researches especially in China are still rest on theorization or static record of historic data, there are few literatures about the quantitative analysis of the driving factors and their effect, which are able to bring a comprehensive look of the process. Many conclusions are based on some "classic" theories formed in 1970s' despite of the new phase or different case of the urban fringe's development. Actually, Urban growth is not a universal process with similar attributes in world regions but a set of complex phenomena conditioned by various culture and historical forces in different places.(Laurence and Edward, 1981).

So it is necessary to apply some new methods to understand urban fringe better with special reference to some case areas in China. Among the widely used dynamic models, CLUE model is a very useful tool to understand driving factors underlying land use process thoroughly. To find possible and precise factors, CLUE model can be combined with DPSIR model.

In this research, the CLUE model will be developed and implemented to study the spatial pattern of urban fringe's development in Wuhan. The case study area is located in the urban fringe of Wuhan, China. Systematic research on special cases can be beneficial to local planning systems. With the simulation of CLUE model, the possible future spatial pattern can be presented.

1.3. Research aim and objectives

1.3.1. The aim of this research

The main aim of this research is to make a contribution to develop Wuhan's urban fringe reasonably and suitably.

1.3.2. Main objectives

The main objective for this research is to gain understanding of factors explaining the development of one urban fringe area in Wuhan and simulate the trend of the case study area's development.

1.3.3. Sub objectives

To achieve the main object, several main aspects will be included:

1. To identify the possible factors affecting land use change in urban fringe

2. To find out the essential factors through logistic regression model
3. To develop the CLUE model for the case study area
4. To present the future land use patterns with different alternatives

1.4. Research questions

The following research questions are to be questioned and investigated through the research.

- To identify the possible factors affecting land use change in urban fringe

  What is urban fringe?
  Which factors will influence the land use pattern of urban fringe?
  Which factors will influence the land use pattern of urban fringe in Wuhan?

- To develop the CLUE model for the case study area

  What is CLUE model?
  Why CLUE model is chosen to do the research?
  How to develop CLUE model for case study area?
  What kind of data does this model need? How to convert these data?

- To find out the essential factors through logistic regression model

  What is logistic regression model?
  How to represent the factors in variables?
  How to remove spatial autocorrelation?
  How to validate the logistic regression?

- To present the future land use patterns with different alternatives

  How to visualize the land use patterns?
  How to generate scenarios for different alternatives?
  What is the future land use pattern?

1.5. Methodology

To achieve the objectives of this research, the work should be done step by step. In detail, their relations and sequence can bee seen in the following figure.

First of all, by literature review relevant concepts of urban fringe will be defined. The framework of CLUE model will be introduced. In detail, to the former, the definition, the characteristics and the related problems of urban fringe in China will be indicated. Then the concept and meaning of modelling will be found. Correspondingly the components and applications of CLUE model will be introduced.

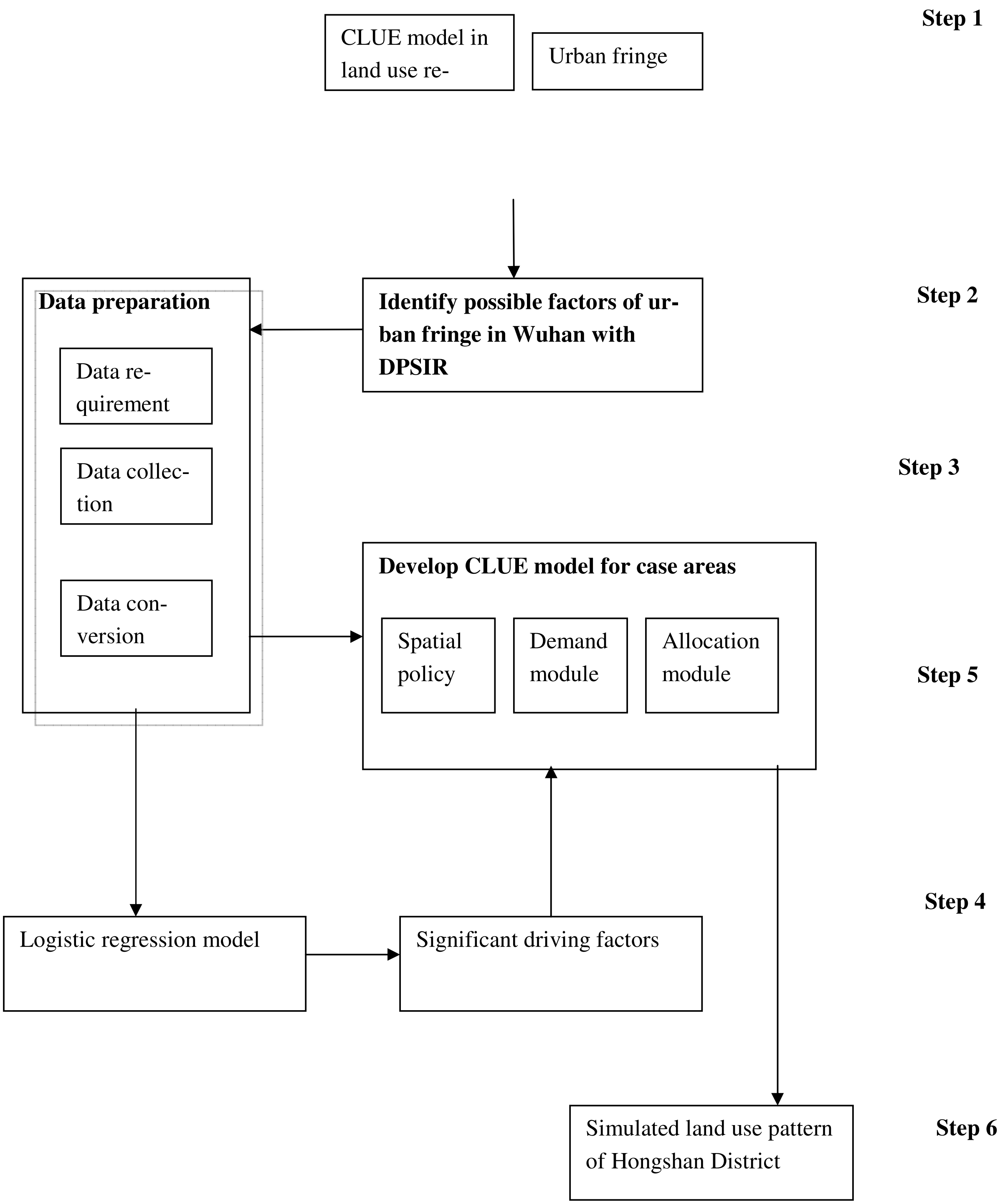

Figure 1.1Research methodology

In the second step, model factors will be identified. Without finding out the proper driving factors underlying the urban fringe in Wuhan, this research would be meaningless. So it is very important to reveal these factors not only clearly but also carefully. This task will be done by the combination of literature review, fieldwork and expert interview. Literature review can give an overview of some common factors. To the case area, it is better to understand its different local system by fieldwork and expert interview. To understand these possible factors better, DPSIR model will be introduced.

In the third step, the data will be prepared and the relevant parameters of the CLUE model will be set accordingly.

In the forth step, the essential factors behind the land use change of Hongshan will be found out through logistic regression model.

In the penultimate step, the demand module and area restriction module will be defined in the developed CLUE model.

Finally, scenarios generated from CLUE model will present the possible land use patterns.

1.6. The outline of the theisis

Chap 1 briefly introduces the research background, problem, objective, and research question as well as the methodology of this thesis.

Chap 2 introduces the related concepts of urban fringe and the situation of urban fringe in China, especially in Wuhan. Particular attention will be paid on the urban fringe driving forces and influence factors. DPSIR model will be introduced for its relatively simplify describing the complex system. CLUE model is also introduced for its usability for this research among the urban modelling methods.

Chap 3 introduces the study area, an urban fringe area of Wuhan city, in China. Basically the natural condition and social economic development are described briefly. The reason why the district is chosen will be explained.

Chap 4 is the methodology part. The influencing factors are identified with the help of DPSIR model. The demand module and area restriction will be developed for the case study area.

Chap 5 is the core of this thesis. In this chapter, the determinant factors are found out on the basis of results of logistic regression. The possible land use pattern will be presented.

Chap 6 is the conclusion part. The meaning of CLUE model combined with DPSIR will be discussed. Finally conclusions with reference to the research objectives are given.

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2. Urban fringe and CLUE model

2.1. Introduction

In this chapter, the related theory background will be introduced and the related influencing factors will be identified.

First part is to understand the urban fringe. Its concept, characteristics and driving factors will be articulated.

Second part aims to review urban modelling methods. The concept and meaning of modelling are to be formulated and some widely used urban models will be introduced.

Finally, a modelling method, CLUE model, will be introduced, focusing on its framework, components and applications.

2.2. Understanding urban fringe

While over the last 20 years urbanization rates in the western countries have stabilized and even in some countries decline, urban growth in the developing countries has risen dramatically especially in China. Indeed, most of this urban growth is occurring on the urban fringe in China as the consequence of urban expansion.

Douglas Webster (2002) defined the development of urban fringe as peri-urbanization process. He referred it to a process in which rural areas located on the outskirts of established cities become more urban in character, in physical, economic and social terms, often in piecemeal fashion. Peri-urban development usually involves rapid social changes as small agricultural communities are forced to adjust to an urban or industrial way of life in a very short time. Peri-urbanization often occurs round one main core city… In Southeast Asia peri-urbanization is the main urban growth form and China is exception, especially from the time, when China has implemented the Open Door policy.

Since the end of 1980's, Chinese urban scholars and planners have been intrigued by the transitional area and begun their systematic studies. According to their main results, the related concepts and theories will be introduced in this section.

2.2.1. Definition of urban fringe

Despite of many terms such as "peri-urban area" and "urban-rural fringe", "urban fringe" is chosen here to label this zone of China. Because in China urban activities are still the main forces behind the fringe's development while rural origins have less influence, in other word the centripetal effects of rural can hardly penetrate into the urban fringe. Different from the zone in western countries, "urban fringe" is a better term used in China indicating its urban bias.

The existence of a grey zone between town and country has a long time excited many social scientists. The 'rural-urban continuum' debate of the 1960's is just one of the more famous expressions of this.

The outcome of this debate seems to be twofold: there is not one single continuum between rural and urban, but instead, there are many that don't necessarily correlate. And secondly, thinking in terms of a continuum makes one underestimate the amount of tension (dichotomy) that also exists between the two ends of the continuum.

The concept of an urban fringe is not a new one in urban geography; there has been a proliferation of definitions referring to the zone of transition between urban and rural.

A Germany geographer, H.Louis (1936) was the first scholar focusing on the concept of urban fringe when he contributed himself to the research of Berlin's urban structure. He named the fringe area as "stadtranzonen"(see figure 2-1). Wahrwein (1942) defined the zone as "the apparent transformation area of industrial and residential area. M.R.G.Conzon (1960) said urban fringe was not only an explanatory method of landscape change, but also a way to relief chaotic urban change. He thought the urban fringe is the foreland of the periodical urban expansion.

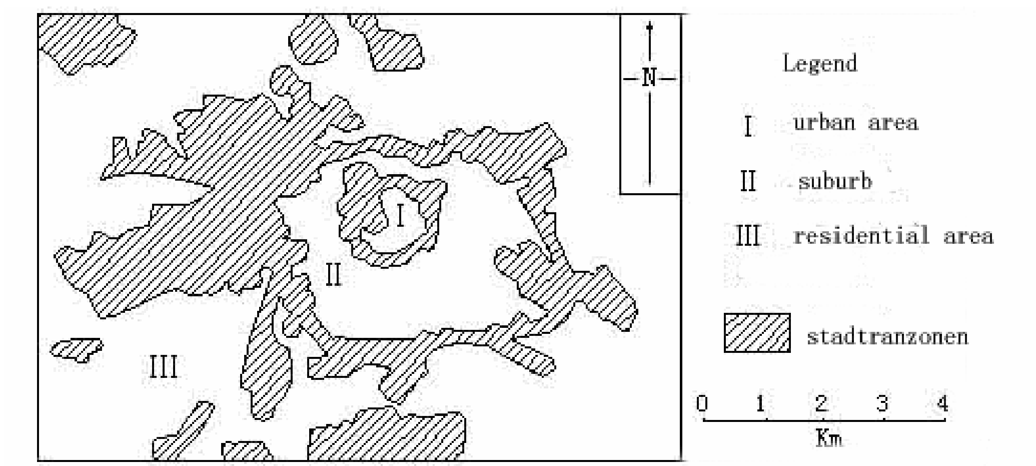

Figure 2.1Urban fringe of Berlin city, 1936

Among the so many definitions, the one proposed by R.J.Pryor is mostly accepted and widely cited. He stated in 1968: urban fringe is the transitional zone of land use. It is located between the two more readily defined poles of urban and rural. The zone has dual characters of urban and rural. Its population density is lower than urban centre's but higher than country's.

Pryor's definition, discussed above, concludes with the statement that fringe characteristics: differ zonally and sectorally and will be modified through time. Here Pryor's definition is used as the frame of reference for my research.

2.2.2. Problems of urban fringe in China

The transitional, flux character, combined with lower and inadequate level of integration and development of the urban fringes, with consequent concentration of worse-off sections in its boundary is the major source of the problems facing urban fringes. In this sense, fringe area is a problem area. (K.N.Kabra, 1980)

In China, the development of urban fringe makes the different way from that of other countries. It has the characteristic that urban expansion and rural-urbanization promote simultaneously. But suburbanization still doesn't become the trend in Chinese urban fringe, in this sense urban fringe relies on the urban.

Cuo (1989) summarized the main problems of Chinese urban fringe:

1 The construction of urban fringe is very disordered because of the lack of effective planning polices and theoretical guidance, so there are a lot of problems in achieving an appropriate balance between urban development and resources and environmental protection.
2 Since urban fringe is situated in city-country combinative area that is no longer rural but is not yet urban, its planning is not only different from that of rural, various built-up area, but also different from that of rural, various index of planning is uncertain.
3 Uban fringe is also a dynamic zone that is undergoing because of it contact with the city, the contradictory of city's expansion and farmland is very prominent, city's expansion caused the heavy loss of prime farmland of fringe.
4 The social and industrial structure of fringe is not stable, economic system is very complex and economic activities and resources tend to focus on the short-term benefits.

More than 10 years have passed, but the above problems still exit. Moreover, some followed new problems emerge.

1 The construction of infrastructures lags the development of urban fringe
2 Illegal land use tenure becomes the common phenomenon
3 The environments of urban fringe are deteriorated seriously

Chinese urban researchers have realized that how to solve these problems is an urgent work in this hot-point area.

2.2.3. Characteristics of Chinese urban fringe

Urban fringe is characterised by a large diversity, which shows itself in complicated infra structural patterns, a complicated system of living-work relationships and a big variety in land value, and a very rapid development, like rapid changes in the size of build area, changes in the functionality of the area and changes in the composition and activities of the population (Pieter van Teeffelen and Steven de Jong, 2000).

Chinese urban fringe is a more complicated area comparing with western countries. It has its own characteristics. According to some Chinese researchers' results, the characteristics of Chinese urban fringe are often classified as below.

- Population characteristic

The population density of urban fringe is intervenient between urban's and rural's(see figure 2-2 the density of population in the Wuhan city). The composition of population in urban fringe is complex for kinds of people with different cultural and professional background flow into this area, mixing with local peasants. Despite the apparent diversity of fringe communities, over the last twenty years conceptualizations of the urban fringe have depicted this space as a "transitional zone" between rural and urban areas that is populated mainly by low-income residents, recently arrived from rural areas or lower-order towns and cities, and engaging in multiple economic activities, usually informal (J.O.Browder, J.R.Bohland and J.L.Scarpaci 1995).

Generally rural population has a higher percentage. The rapid growth of population is remarkable in urban fringe. it not only attributes to the high increase percentage of local population, but to the in-burst of enormous people from other areas.(Gu 1993; Wei 2000)

- Administration characteristic

When the cities expand, they tend to "eat" agriculture surplus or agriculture land spontaneously. Then it is inevitable for the development of urban fringe to cover sever administrative boundaries. Consequently, the management of the urban fringe are incapable when the governments are arguing with the area's ascription. Even administrative inclusion of urban fringes in the main city does not necessarily and by itself contribute to the solution of the problems of urban fringes. In fact, it may produce counter effects (K.N.Kabra 1980).

- Social characteristic

Although peri-urban areas are often ethnically heterogeneous, socioeconomic class distinctions and conflicts over land and labour abound. (Swindell 1988)

Coming to the occupations in the urban fringe, most of local villagers have dual occupations: peasants and workers. They spend much longer periods working in the factories, but return to their agricultural fields at more or less regular intervals determined by agricultural seasons or religious holidays (Prothero and Chapman 1985; Hugo 1987).

Not like the thing assumed as a matter of course, actually the average literacy level of this area is not lower even higher in some cases than that of urban because a lot of science institutes and universities would like to choose their sites at urban fringe. Obviously, a great literacy disparity exits.

Just as discussed above, the urban fringe may or may not be administratively integrated with the core city. So the management of the urban fringe is far from effective. It becomes a vacuum area or breeding ground for crime-ridden social phenomena.

- Economic characteristic

Among the agricultural activities in urban fringe, cropping vegetable and feeding cattles contribute more to fringe's agriculture. Indeed for most of large cities, urban fringes are their main food supply zones.

The form of economic structure in the urban fringe evolves very quickly and brings along the development of rural area. Knowledge concentrated industry and labour concentrated industry coexist in this zone. It should attribute to the preference to urban fringe of informational industry's site selection and also the booming township industry.

- Ecology landscape characteristic

As the transitional area between urban and rural, fringe landscape is a composite of urban landscape and rural landscape. It may not be surprised to see farms around high modern buildings. Here landscape is mussy responsible for its fractional land uses.

Large cities prefer to deposit their garbage on the fringe area. Thus sorts of pollution phenomena are ubiquitous and it results in that the environments in urban fringe are deteriorated seriously.

- Land use characteristic

Having seen that the urban fringe is very attractive for a great variety of users, both from the agricultural and the urban point of view, one should not be surprised to find not only many land uses intermingled but also transitional forms of land use (Pryor 1968).

In fact the diversity of land uses is inevitably described in case land use in the urban fringe is referred to. Firey (1946) wrote about the 'conglomerate of land uses', Wissink (1962) explained the 'particular arbitrary and capricious character' of land use in the fringe, and Carter (1981) about a 'wide mix of land uses'. Thomas (1974) mentions 'farming-to-quit' and completely idle land as examples of transitional forms of land use. Referring to the peripheral zones of towns in East Germany, Richter (1974) wrote that 'elements susceptible to certain disturbances (residential quarters, recreation grounds) often border with those that cause them.

Similar problems are recorded by Wei (2000) from the fringe of Shanghai, Nanjin and Wuhan. Land use confusion is thus not confined to western countries but a distinct feature of land use in the Chinese urban fringe.

The land use pattern is complex and dynamic in the urban fringe. Land use change is not only the conversion from non-urban land to urban land, but also exits in the competition between the divers land uses. In the Chinese urban fringe, the urban land use is extensive compared with the intensive cultivation of agricultural land. Because most of urban land uses occupy large areas with low building density, while to agriculture the fringe is a better area for the farm market economy due the proximity to the market. Moreover, agricultural land parcels are usually intersected by the infrastructure nets with the rapid construction of infrastructures in the fringe.

2.2.4. Driving forces behind urban fringe's development

Although the development of urban fringe goes with urban growth, but the driving forces underlying its development are different from those of urban growth.

In general, L.M..Van den berg (1984) summarized the forces as two traditional terms: centrifugal forces and centripetal forces. He referred that types of rural land use that are attracted most to the urban fringe include market gardening and intensive horticulture, but also horse-ridding schools, dog kennels and piggeries. The pressure from such types of rural land use constitutes what could be called centripetal forces in the urban fringe. Two main types of centrifugal forces were considered: the withdrawal of agricultural land uses and the entry of urban ones. On the other hand, there are also many urban land users who re not able to operate in more central locations. Such centrifugal land uses include lorry-oriented factories, noisy, smelly or dangerous industries, but also recreation facilities and home seekers. The similar viewpoints were ever applied into the research of Chinese urban fringe (Cheng 1995).

In more detail exploration to the driving forces will be formulated below.

- Driving forces behind urban fringe's development in western countries

Based on the conclusions from the extensive researches on the suburbanization of U.S, transport technology is the essential force for the development of urban fringe. The widespread cars and the advanced transportation system bring cities more chances to grow in a larger area. It thus liberates the western cities from the traditional single-core pattern and evolves them to multi-core or non-core ones with the city's expansion along the main roads. The economic activities in the urban fringe didn't need to worry about how to proximity to the city markets, contrarily they may be pleased with the situations adjacent with airports. Surely it would motivate the development of urban fringes.

The rapid development of high technology also accelerated urban fringe growth. With those infant industries becoming the leading ones, these high-tech enterprises, most of which were located in urban fringe, offered more employment opportunities. Meanwhile it generated a new middle social class who greatly contributed to the large migration from urban centre to the urban fringe.

Government policy and urban planning, which are greatly affected by the conception of 'garden city', help the urban fringe more rationally and harmoniously. The planning idea of 'Garden city' argued with decentralization city strategy that encouraged suburb's development.

As the baby boomers grew up and married, the houses in the city centre could not fulfil their demands so they transferred their attention to the urban fringe. It was to some extent stimulate the urban fringe's development.

Another force can also be considered is the psychological character of people in western countries. They would like to see some new things, move freely, emphasis individuality and prefer nature. Urban fringe is such a desirable area for them.
From above forces, it can be concluded that the development of urban fringe in western countries is high motivated by the residential migration to urban fringe. It is different from China.

- Driving forces behind urban fringe's development in China

In China, like urban growth the development of urban fringe is also a more complex progress than western countries. To different areas or different periods, the corresponding driving forces may change. Here I just give some universal forces behind Chinese urban fringe.

Fist of all, nature and topography conditions are the external forces underlying the development of urban fringe. Soil fertility, terrain and climate have high effects on the agricultural activities. Fringes have suitable natural environments and flat topography surrounding the city will win a better develop platform with the lower cost of exploring land.

Economic growth is absolutely one of the forces based on the definite argument that urbanization is pushed by the economic growth. It also can be seen that urban fringe has the same periodical development as the economic growth. Not like the residential land arises greatly in the fringe of western countries, industrial land (e.g. Industry Park, Township Industry…) is explored firstly in Chinese urban fringe. And then other land uses come forth.

Transportation and communication development are the forces that are able to accelerate the development of Chinese urban fringe. More and more high-speed ways are built, public transportation system has made a great process and cheaper private cars can be purchased by more Chinese citizens…all these endue urban fringe with high accessibility.

Entirely different from the western countries, government policy and controls highly accelerate or constrain the development of urban fringe. For example, the building of large industrial zones, relocation of heavy industry, encouragement of township industry's development and unique administrative pattern are usually happening in the urban fringe affected by the policies or plans.

Social culture environment and people's psychological characters are the forces that should not be neglected. Some researches have shown that people no longer have the strong desires live in the urban centre as before. It may result in more people flow into the urban fringe.

2.3. Modelling as tools to understand land use change

In this part the question that why land use modelling are used will be answered and the hopeful mode CLUE will be introduced from its structure to application.

2.3.1. The meaning of modelling

In 1970s, Peccei stated one purpose of modelling lies in the need of communication. That is to say, modelling can help people communicate with each other more easily. Bender in 1994 answered the remaining question. In his Ph.D thesis he argued that the second meaning of modelling is to reduce uncertainty (R.M.J.Benders 1996).It means with the help of models, we can further our understanding about the complex world, enlarge our knowledge, and reduce our uncertain understanding about our surrounding world.

With the help of modelling and simulation, we can reduce uncertainty and increase our understanding of urban system. Take urban planning process as an example. Planning is a future-oriented activity, strongly conditioned by the past and present, planners need to enhance their analytical, problem solving and decision making capabilities. With the help of models, it can facilitate scenario building and provide an important aid to future directed decision- making (Cheng 2003a).In this way, urban planning can be more scientific and reduce the subjectivity brought by decision makers.

Furthermore, by modelling urban system, people can understand its functions better and further the theory research of cities. Meanwhile, by modelling urban system, researchers can test and evaluate some theoretical hypotheses and ideas in a controlled environment, since different urban models work as different social labs, where various experiments can be done. It equips urban research in a more experiment method comparing with past pure theoretical research (Jiao 2003)

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A model can serve as a good tool to mimic part of the complextity of the land use system. It offers the possibility to test the sensitivity of land use (pattern) to changes in selected variable and the stability of the entire system by executing a range of scenarios. While a model will always fall short incorporating all aspects of the 'real world', it provides valuable information on the system's behavior under a range of different future pathways of land use change.

2.3.2. Development of land use modelling

The rising awareness of the need for spatially explicit land-use models within the Land-Use and Land-Cover Change research group (LUCC; Lambin and others 2000a, Turner and others 1995) has led to the development of a wide range of land-use change models. Whereas most models were originally developed for deforestation, more recent efforts also address other land use conversions such as urbanization and agricultural intensification. Spatially explicit approaches are often based on cellular automata that simulate land use change as a function of land use in the neighbourhood and a set of user-specified relations with driving factors. The specification of the neighbourhood functions and transition rules is done either based on the user's expert knowledge, which can be a problematic process due to a lack of quantitative understanding, or on empirical relations between land use and driving factors. A probability surface, based on either logistic regression or neural network analysis of historic conversions, is made for future conversions. Projections of change are based on applying a cut-off value to this probability surface. Although appropriate for short-term projections, if the trend in land-use change continues, this methodology is incapable of projecting changes when the demands for different land-use types change, leading to a discontinuation of the trends. Moreover, these models are usually capable of simulating the conversion of one land-use type only (e.g. deforestation) because they do not address competition between land-use types explicitly.

2.4. CLUE model

Spatial models of land use change are important tools to analyse the possible trajectories of land use change in the near future. The results of land use models are important to evaluate policy options and assess the impact of land use change on natural and socio-economic conditions.

The Conversion of Land Use and its Effects modelling framework (CLUE) (Veldkamp and Fresco, 1996; Verburg et al., 1999) was developed to simulate land use change using empirically quantified relations between land use and its driving factors in combination with dynamic modelling of competition between land use types. The model was developed for the national and continental level.

Land use data for study areas with a relatively small spatial extent is often based on land use maps or remote sensing images that denote land use types respectively by homogeneous polygons or classified pixels. This results in only one dominant land use type occupying one unit of analysis. Because of the differences in data representation and other features that are typical for regional applications, the CLUE model cannot directly be applied at the regional scale. Therefore the modelling approach has been modified and is now called CLUE-S (the Conversion of Land Use and its Effects at Small regional extent). CLUE-S is specifically developed for the spatially explicit simulation of land use change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems.

2.4.1. The structure of CLUE model

The model is sub-divided into two distinct modules, namely a non-spatial demand module and a spatially explicit allocation procedure (figure 2-2). The non-spatial module calculates the area change for all land use types at the aggregate level. Within the second part of the model these demands are translated into land use changes at different locations within the study region using a raster-based system. The user-interface of the CLUE-S model only supports the spatial allocation of land use change. For the land use demand module different model specifications are possible ranging from simple trend extrapolations to complex economic models. The choice for a specific model is very much dependent on the nature of the most important land use conversions taking place within the study area and the scenarios that need to be considered. The results from the demand module need to specify, on a yearly basis, the area covered by the different land use types, which is a direct input for the allocation module.

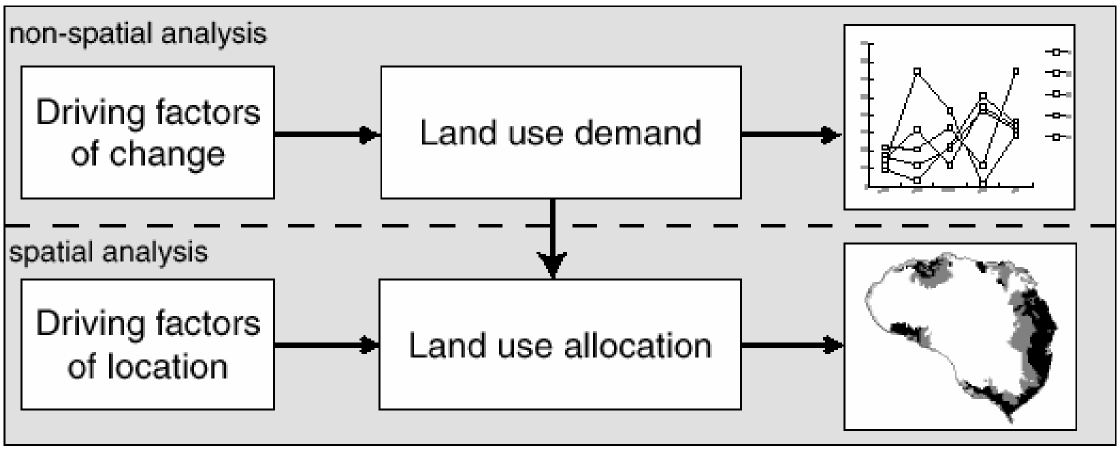


Figure 2.2 Overview of the modelling procedure

The allocation is based on a combination of empirical, spatial analysis and dynamic modelling. Figure 2-3 gives an overview of the information needed to run the CLUE-S model. This information is subdivided into four categories that together create a set of conditions and possibilities for which the model calculates the best solution in an iterative procedure. The next sections discuss each of the boxes: spatial policies and restrictions, land use type specific conversion settings, land use requirements (demand) and location characteristics.

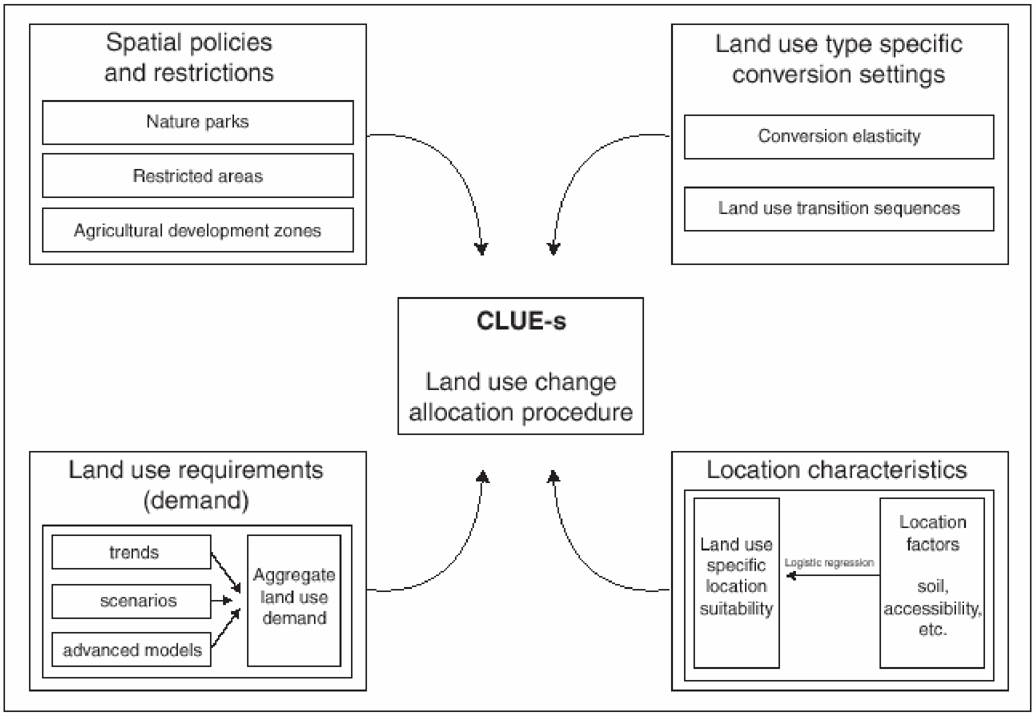


Figure 2.3 Overview of the allocation procedure

2.4.2. The general framework of CLUE modeling

The CLUE (Conversion of Land Use and its Effects) modelling framework has been designed to explore near-future changes in the spatial pattern of land use in Costa-Rica (Veldkamp and Fresco, 1996). The study for Costa-Rica describes where 'hot-spots' of land-use dynamics are probable for a series of different scenarios including variations in urbanisation rate, protection of national parks and biophysical feedback (Veldkamp and Fresco, 1997a).

The tools that make up the CLUE modelling framework are developed with the objective to:

- Provide insight into the spatial variability of land use and its determinants
- Indicate which (proximate) factors determine the spatial distribution of land use
- Account for the scale-dependency of these relations
- Indicate potential near-future 'hot-spots' of land-use change for realistic scenarios

The CLUE modelling framework (see figure 2-2) provides tools to obtain insights into the complexity of the land-use situation as well as tools to explore and quantify near-future pathways of land-use development. This information is meant to serve the effective design of land-use plans in the designing phase. As the CLUE modelling framework primarily is used at relatively coarse scales, additional information at more detailed scales is needed to fully understand the processes involved. Socio-economic, actor-oriented, studies provide a useful tool to investigate these fine scale dynamics. This type of studies could be targeted at 'hot-spots' identified at coarser scales.

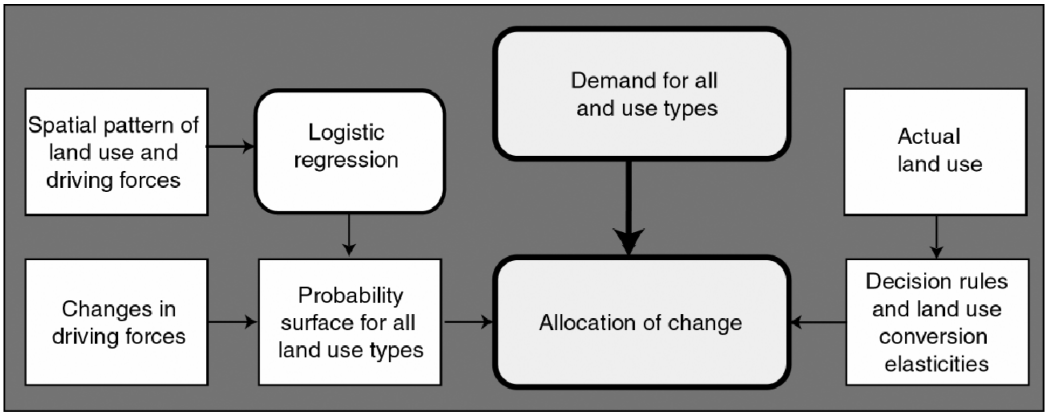


Figure 2-2 The framework of CLUE model

2.4.3. Characteristics of CLUE model

P. Verburg (2000) stated the characteristics of land-use systems provide a number requirements for the modelling of land-use change that have been used in the development of the CLUE-S model, including:

Models should not analyze land use at a single scale, but rather include multiple, interconnected spatial scales because of the hierarchical organization of land-use systems.

- Special attention should be given to the driving factors of land-use change, distinguishing drivers that determine the quantity of change from drivers of the location of change.
- Sudden changes in driving factors should not directly change the structure of the land-use system as a consequence of the resilience and stability of the land-use system.

In generally, CLUE has three main characteristics as below:

- Spatial representation
- Empirical/statistical characterization of location ‘suitability’
- Dynamic modeling of complexity

2.4.4. Multi-scale approach

The CLUE model includes two spatially explicit scales at which land use is allocated in addition to the aggregated national scale on which demands are calculated (Figure 2.4). These allocation scales are artificial aggregation levels consisting of grid-based data at two different resolutions. A relatively coarse scale is used to calculate the general trends of the changes in land-use pattern and to capture the influence of land-use drivers that act over considerable distance. Based upon the general pattern of land-use change calculated at this coarse allocation scale, but taking local constraints into account, the land-use pattern is calculated at a finer scale level. Depending on the application, area studied and data availability the resolution of analysis will vary.

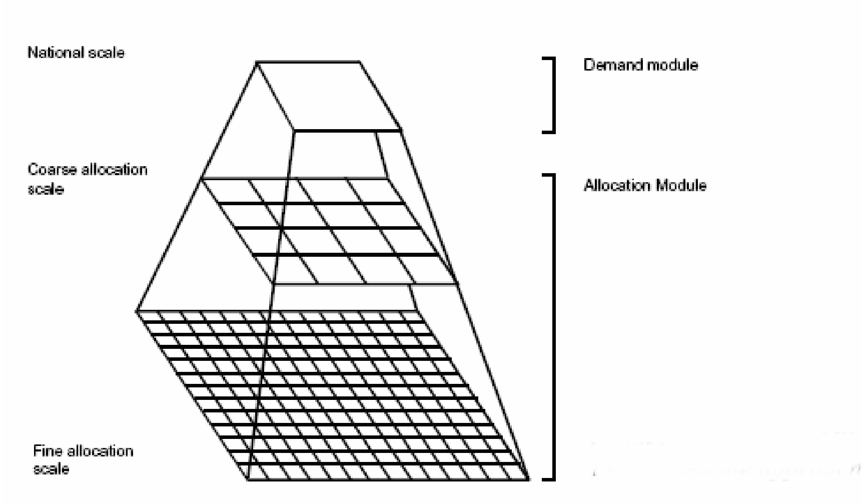


Figure 2.4 Schematic representation of the multi-scale approach

2.4.5. Statistical analysis

Statistical techniques are well suited to achieve the investigative aims here. Simple correlation analysis was used to quantify the relation between individual candidate explanatory factors (independent variables) and the land-use distribution (dependent variables). If no common pattern exists for a candidate explanatory factor, the correlation will likely reflect this in insignificant results. It is essential to emphasis that an explanatory variable found to be significantly related to the land-use distribution, does not necessarily imply that it is a direct cause of the land-use pattern; correlation does not necessarily imply causality.

Multiple regressions are used to derive comprehensive models that describe the pattern of land use as a function of a combination of explanatory factors. Multicollinearity is very common in studies of complex systems, as many candidate explanatory factors are closely related (e.g., geomorphology and soil). A step-wise regression procedure was used to select only the factors that yield a significant ($P<0.01$) contribution to the regression model. For each regression equation the adjusted coefficient of determination (adj-R2) is a measure for variation in the relative cover of the specific land-use type that can be explained by the model variables. The standardised betas indicate the number of standard deviation changes in the dependent variable associated with a standard deviation change in the independent variable if all other variables are held constant. They are therefore indicative for the relative importance of a variable for land-use change in a given regression equation (equation 1).

$$\mathbf{P(y) = \beta_0 + \beta_1 x_1 + \beta 2\ x2 + \beta 3\ x3 + \beta 4\ x4 + \beta 5\ x5 + \ldots} \qquad (1)$$

For reasons of simplicity we have only evaluated linear regression. This approach might decrease the explaining power of the regression models, as some explanatory factors will be related to land use in a non-linear way. However, relationships that are non-linear at fine scales tend to be flatter (i.e., more linear) at coarser scales (for details see the discussion by Rastetter et al., 1992). An exploration of the data set indicated that at all scales considered in this study the relations are well represented by linear models.

Geographical patterns nearly always exhibit positive spatial autocorrelation. Stronger spatial autocorrelation indicates a stronger tendency for like values to cluster. So, there is generally a lack of independence present among observations in spatial data sets (Anselin, 1988). In general, autocorrelation results in inefficient parameter estimates and inaccurate measures of statistical significance. Correcting the statistical procedures for autocorrelation is not feasible as no satisfactory methods are yet available to deal with spatial autocorrelation in spatial methods.

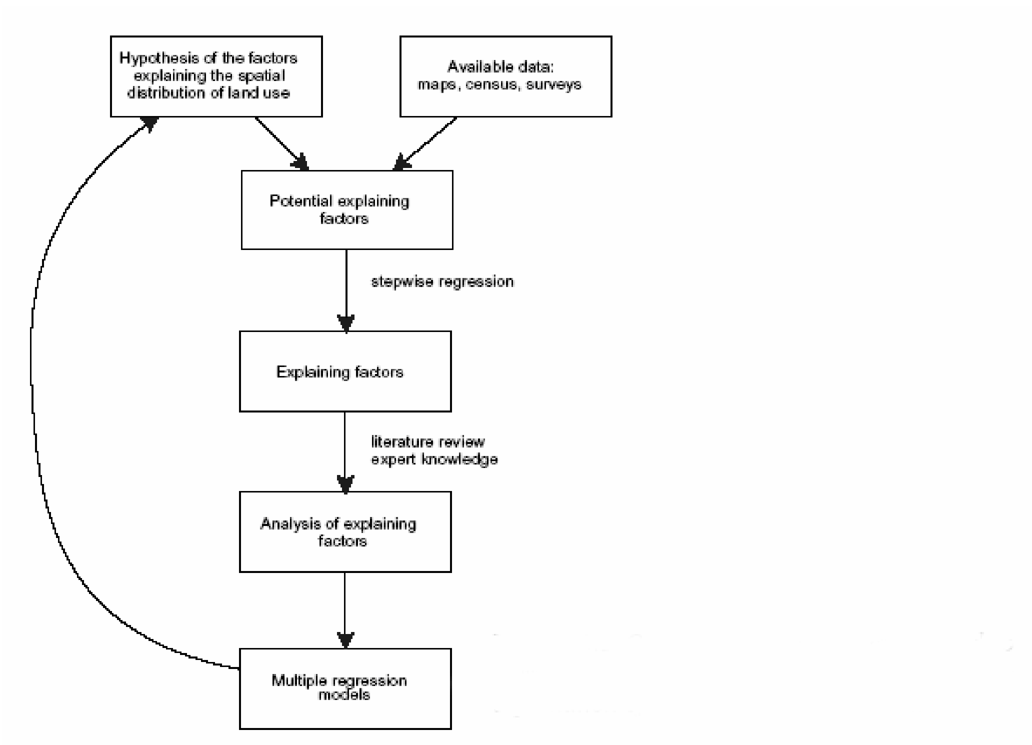


Figure 2.5 overview of the procedure used to derive multiple regression models for the explanation of the distribution of land use

The above figure illustrates the concept of multiple regression equations for the description of the spatial distribution of land use.

2.4.6. The applications of CLUE

The approach used in the CLUE modelling framework to allocate land-use changes attempts to account for the entire system of complex interactions between historic and present land use, socio-economic conditions and biophysical constraints. Interactions between land-use elements and the scale dependency of both the structure and function of the land-use pattern are explicitly addressed as well. So it is applied widely in many fields as well as in many countries (Kok and Winograd 2001; de Koning Koning and others 1999; Verburg and others 2000; Verburg and others1999).

2.4.7. DPSIR model

To understand how the system works, a "process or behavioural" model is required to establish the functional and structural relationships among its elements. DPSIR model (Sharifi, 2004) is such a model that can explain the cause and effect relationships between interacting components of a complex social, economic and environmental system. The conceptual framework of DPSIR is derived from Pressure-State-Response developed by OECD (State of the Environment "SOE" group) and extended by European Environmental agency (EEA). It provides a very useful tool to analyse the interrelated factors.

DPSIR stands for Driving forces, Pressures, States, Impacts and Responses. Just as the figure shows, it is able to know information of the different elements in the DPSIR chain, demonstrate their interconnectedness, and estimate the effectiveness of Responses.

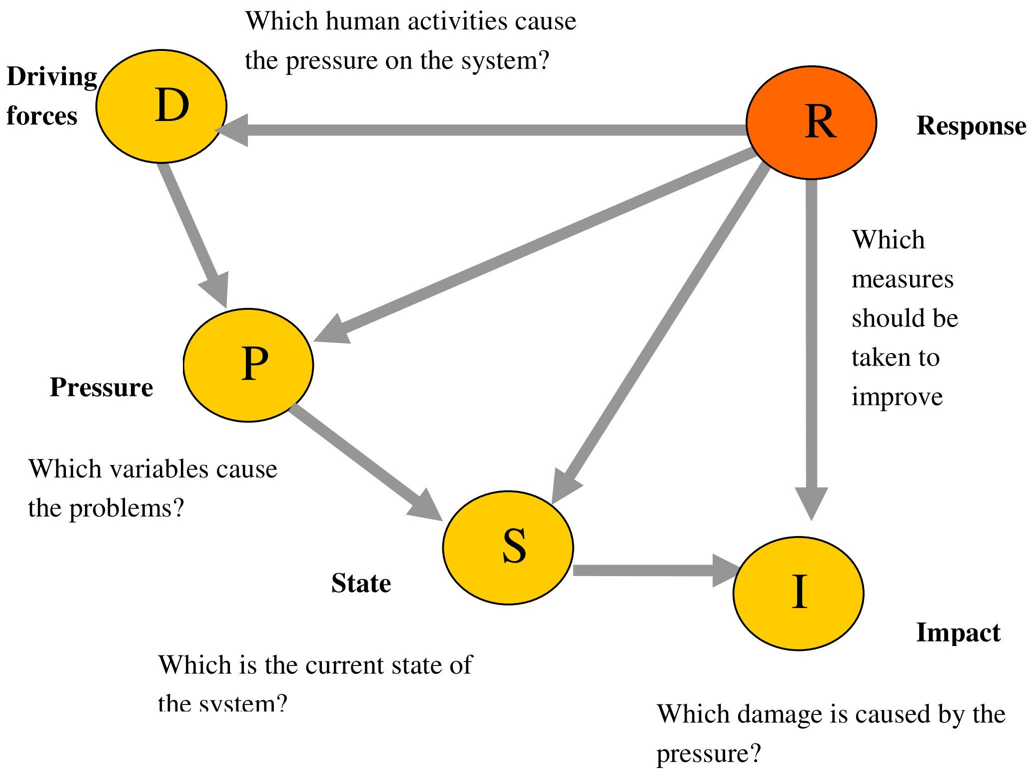


Figure 2.6 The framework of DPSIR

2.4.8. Combine DPSIR with CLUE

Through the discussion above, DPSIR is able to help find out the driving forces behind the complex system. But it is actually based on the logical qualitative analysis. Normally the communication and data integration among its structure is weak. It is still blurry which factors are essential among these possible forces. As mentioned above chapters, CLUE model is a unique tool to find out the relationships among driving factors. In light of these considerations, here DPSIR is attempted to integrate with CLUE model. With the DPSIR, the possible factors will be identified and represented as GIS variables. And calculated by CLUE model, some scenarios and coefficients will be generated. Till then, the possible essential factors are standing to reason. In depth, we can assess the system with these factors again..

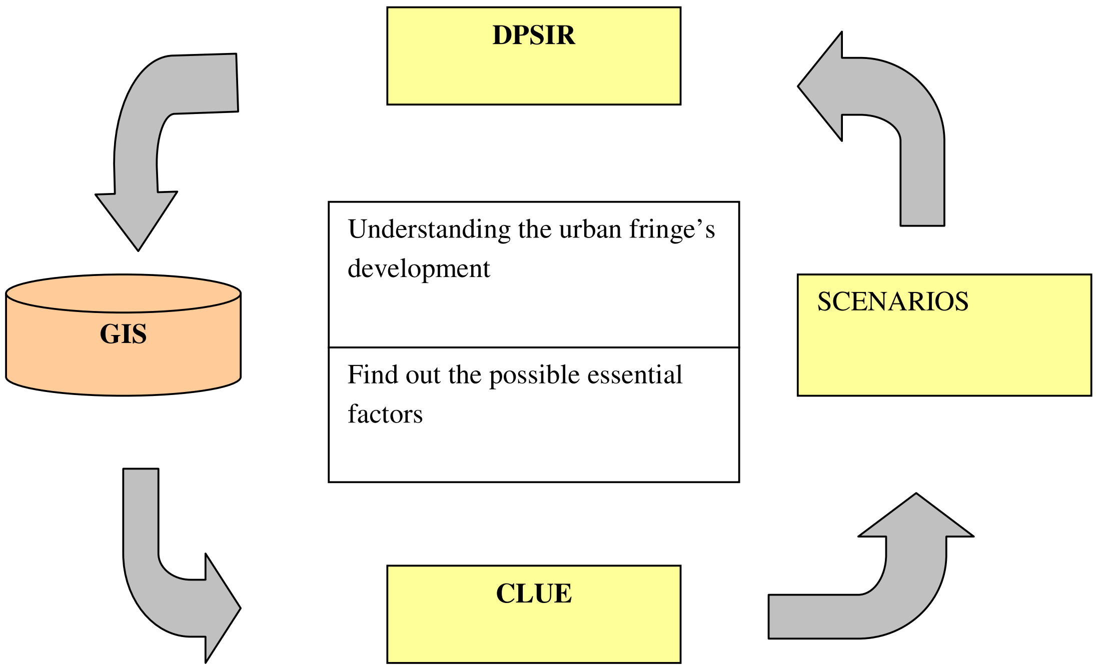


Figure 2.7 Combine DPSIR with CLUE model

3. Case study area

3.1. Introduction of Wuhan

Wuhan city is located in central China and on the middle reaches of the Yangtze River, the third longest river in the world (figure 3-1). It is about 1200km away from other main metropolises such as Beijing and Shanghai. As the capital city of Hubei province, Wuhan is one of the biggest cities in China, with an administrative area of 8494.41sq km and a population of 7,491,943 (till 2002). Its topography is dominated by relatively flat land between 22 and 27 m above sea level. Wuhan has a nicknamed "Water City" for s not only do two rivers (Yangtze and Han rivers) intersect here but the city is also surrounded by a number of lakes. As the Yangtze River and the Beijing-Guangzhou railway line cross here, Wuhan is a junction for water, railway and other traffic in China. Wuhan is a combination of three towns: Wuchang, Hanyang and Hankou.

Wuhan is one of the top 10 largest cities in China as ranked by the total retail consumer spending (No.6 in 2001), output of Gross National Product (No. 9 in 2001), and total Fixed Asset Investment (No. 9 in 2001) (Wuhan Statistical Bureau and Wuhan Development and Planning Committee, 2002). Recently, the municipal government of Wuhan is proposing for a Great Wuhan Economic Region, which aims to parallel in development with the three economic regions along the coast (i.e., the YangtzeRiver Delta Economic Region, the Pearl River Delta Economic Region development in central China).

Along with its economic growth, the urban growth of Wuhan city is also rapid. Physically and functionally the growth is mostly represented in the fringe of Wuhan city for the control of land use in the inner city (shown as figure 3-2). Attention should be paid more to understand the quick and complex development of urban fringe in this big city.

Figure 3.1 Location of Wuhan city

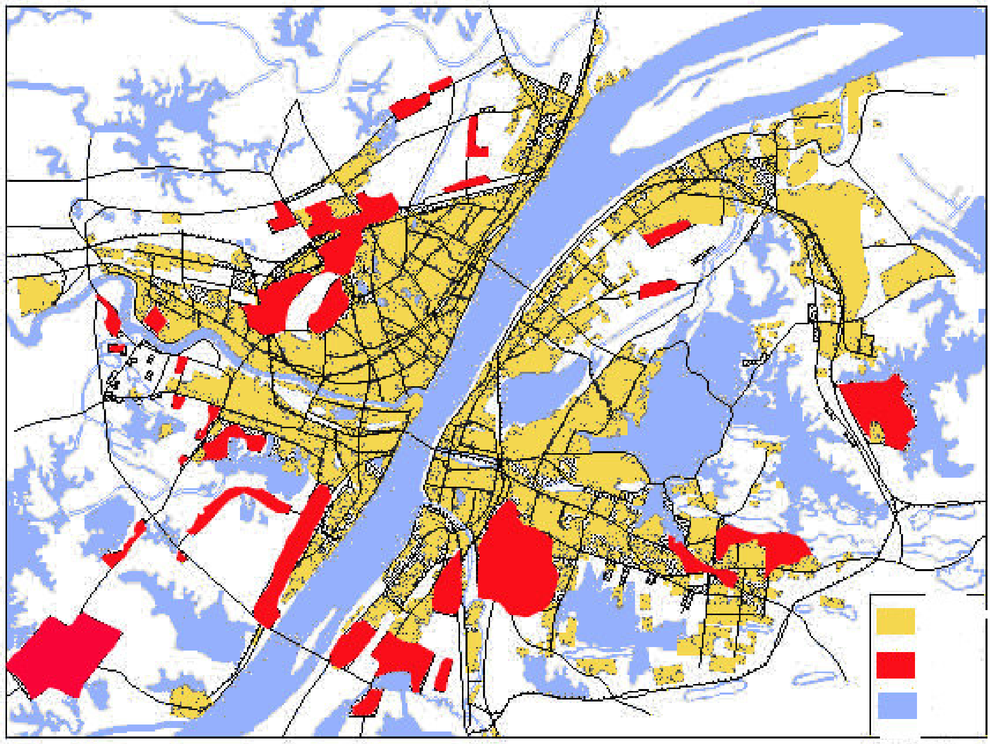


Figure 3.2 Urban development from 1990-2000 red- new urban areas

3.2. General overview of case study area

3.2.1. Location of study area

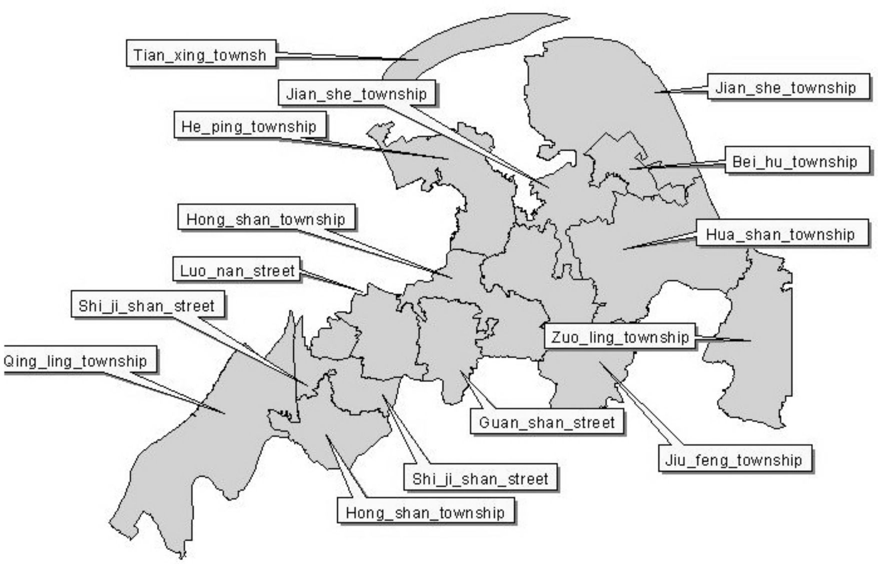


Figure 3.3 Administrative boundary of streets in Hongshan District

The case study area is located in Hongshan District, the east part of Wuhan Municipal City. Hongshan District is a typical urban fringe area where there are both urban and rural areas. It consists of nine rural administrative units (townships) and three urban administrative units (streets): Tianxing township, Jianshe township, Hepiing township, Beihu township, Huashan township, Jiufeng township, Zuoling township, Hongshan township, Qingling township, Luonan street, Guanshan steet, and Shizishan street. (shown as figure 3.3)

It covers an area of 509 square kilometers including 60 square kilometers built-up area. The Beijing_Guangzhou Railway from north to south and the Wuhan-Daye Railway from east to west run across the district. The expressways from shanghai to Chengdu and from Beijing to Zhuhai meet in the zone. The second and third Ring Road of Wuhan city wil run through this district around in 2006.

In my study, effort will not be focused on the whole Hongshan District. The outer fringe area such as Jianshe Township and Huashan Township will not be included into the modeling procedure because the land use patterns in these areas are relatively stable. Another area, Heping Township, is also omitted for its land use is mostly affected by Qingshan District. Therefore the case study area will cover 236.36 km with a population of 477,709 (till 2002).

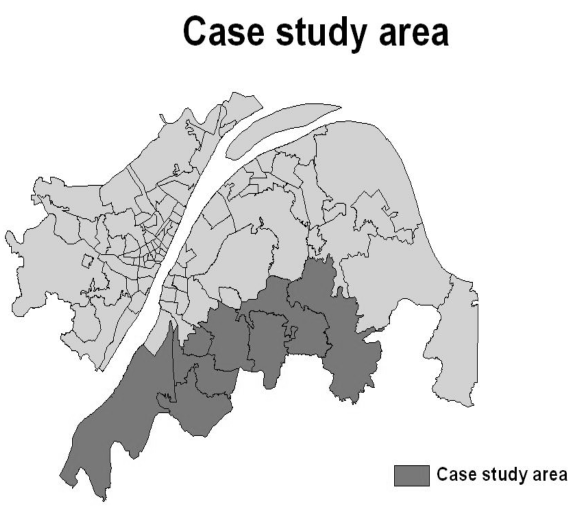


Figure 3.4 Case study area

3.2.2. Economic development

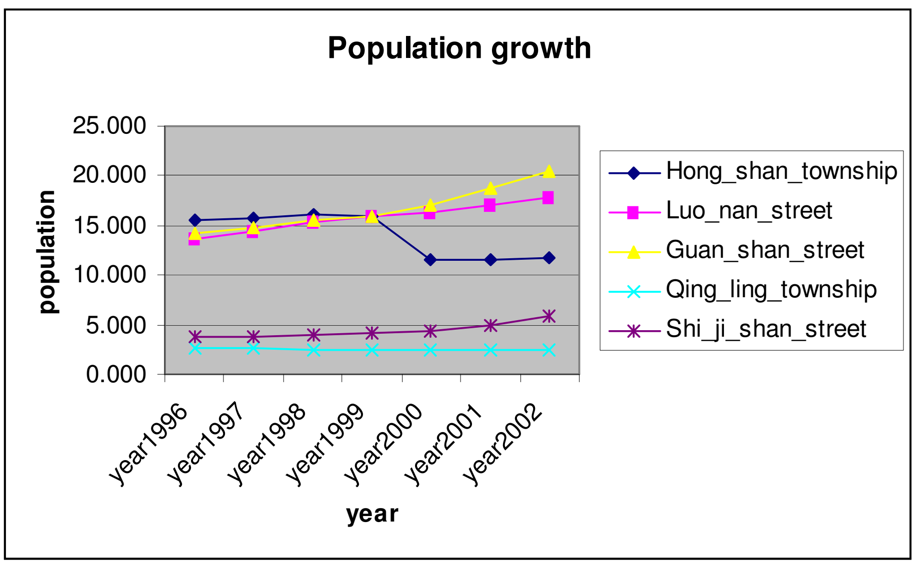
Hongshan District is a hi-and new -tech industrial district with the integration of science, industry and trade, and also an important production base for vegetables and foodstuffs. Hongshan District has also been granted the 'Ten Powerful Districts/Counties' in the province for several years. Hongshan District is the second largest domestic scientific, educational and intellectual concentrated area. It has 23 universities and colleges, 56 state-level scientific research units, 10 important state¡¡ laboratories and 4 state technology centers with more than 1000 scientific research achievements. It is thus eulogized as 'Silicon Valley in central China' and 'the second ZhongguanCun'. The state-ratified Wuhan 'Optical Valley' is situated here. Great attentions have been paid to develop high-tech enterprises responsible for its educational and scientific sources in Hongshan.

FDI (Foreign Direct Investment) is thought as a trigger of economic development. In Hongshan District, besides various preferential policies encourage foreign investors on lands, taxes and charges. Furthermore, several great projects such as Wuhan Baishazhou Merchandise and Communication Developing Group, Hongshan science and technology incubation belt, Jiufeng optical valley industry garden of Hongshan economic development zone, Wuhan Chemical Industrial Development Zone and Wuhan South Lake Hi-and new-tech Agriculture Zone are planned by Wuhan Municipal government. These zones are expected to stimulate the economic development of Hongshan District.

3.2.3. Population

In 1996, the population of the case study area is 357056. As the urban fringe of Wuhan city, its population increases greatly. In 2002, its total population is 477079. But this growth does not take place in every township / street. Table 3-1 indicates that the population of Luonan Street and Guanshan Street grow rapidly with respect to urbanization. Population even deceases in Hongshan Township. It may be attribute to the migration into the former two streets. It is a familiar phenomenon in the development of urban fringe.

Table 3.1 Street population growth in the case study area 1996-2002



3.2.4. Master planning 1996-2020

The master plan 1996-2020 is the blueprint of Wuhan city confronted with the new 21st century. This master plan brings forward the corresponding panning and regulatory objectives to the urban development towards 2020. The plan gives highlights for urbanization of Wuhan. The urbanization level is expected to achieve 80% in 2020. Urban fringe is foreland of urbanization, so the case study area will experience this transitional process. Figure 3-4 presents the land use plan for the case study area. It indicates the case study area is mostly covered by urban land use (residential land, industrial land and so on). At that time, the case study may be not so-called urban fringe area.

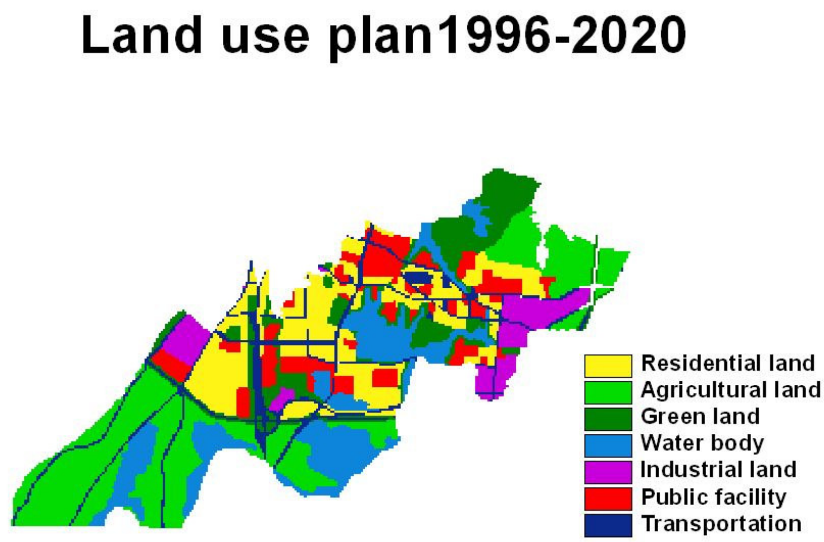


Figure 3.5 Land use plan of the case study area 1996-2020

4. The Conceptual Model

4.1. Introduction

The previous chapter gives the description of case study area. In this chapter, a conceptual CLUE model based on the spatial logistic regression model is developed for the case study area. Firstly, the potential 'hot-spots' of land use changes is identified with the help of DPSIR model. And then the several components including demand module, allocation module, and spatial policies are set up for this conceptual CLUE model. Based on this conceptual model, simulated land use pattern will be obtained in the next chapter.

4.2. Work flowchart

In this section, the procedure of the work for conceptual model will be introduced first (figure 4-1).

The first step is that large quantities of data (land use, road and so on) are integrated from kind of maps using GIS techniques.

GIS just technically provides the spatial data related with land use change. However, land use change is a complex dynamic process. It involves various physical, social and economic factors. The complexity arises from the unknown number of factors, and multi-scale and cross-scale interactions among factors. Further more, different land use has their respective driving factors. So the identification of possible factors underlying different land use is the next step. DPSIR model will be used to find the cause-effect relationships for its ability of describing system in a qualitative way.

Here, the analysis is limited to the qualitative step. The question that which factors are determinant is still needed to be answered. To achieve the objective of finding quantitative estimates of land use drivers, spatial logistic regression is used.

As a successful model, it should have a strong capacity for interpretation and an interactive environment to simulate 'What-if' scenarios. Based on the results of logistic regression and different 'top-down' demands, CLUE model will answer 'where' or 'what' question with its explicit spatial dimension.

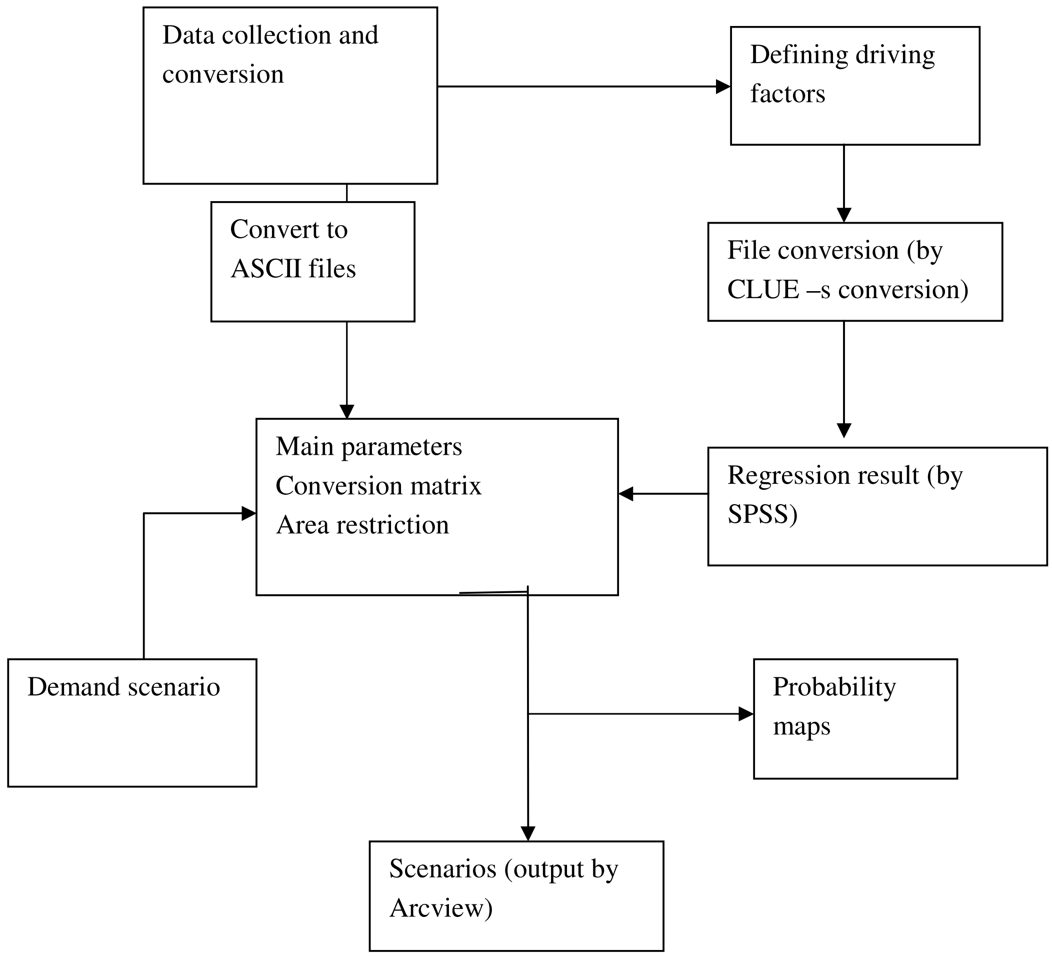


Figure 4.1 Working flowchart

4.3. Land use classification

Before identifying the possible factors behind land use, land us classification is necessary. Too large land use sets will make no sense to find the factors underlying every land use type. In this study, 7 kinds of land use types are formulated derived from the available data (table 4-1).

Table 4.1land use classification

Land-use type	Description
Residential land	Residential areas with accessorial social-cultural facilities
Agricultural land	Arable land, horticulture, orchards, villages, etc
Green land	Open green space, parks, preserved belts, etc
Water	Lakes, rivers, etc
Industrial land	Industries, warehouse, and other service industries
Public facility	Municipal utilities, commercial service, governments, educa-tional land, etc

Transportation	Railway, stations, etc

4.4. Factors affecting land use pattern with DPSIR

In the previous chapter, the general driving forces underlying the urban fringe have been discussed. Here from the spatial aspects of land use change, we will identify those factors behind every land use type with DPSIR model built around driving forces discussed above. The identification here is largely from the literature, experts' knowledge and local planners' feel of the case study area.

4.4.1.1. Industrial land DPSIR

This D-P-S model (figure 4-2) has shown the general relationship between its driving factors, pressure and state with the special reference to industrial land. In the following section, I will explain it in more detail.

What drives the industrial land development?

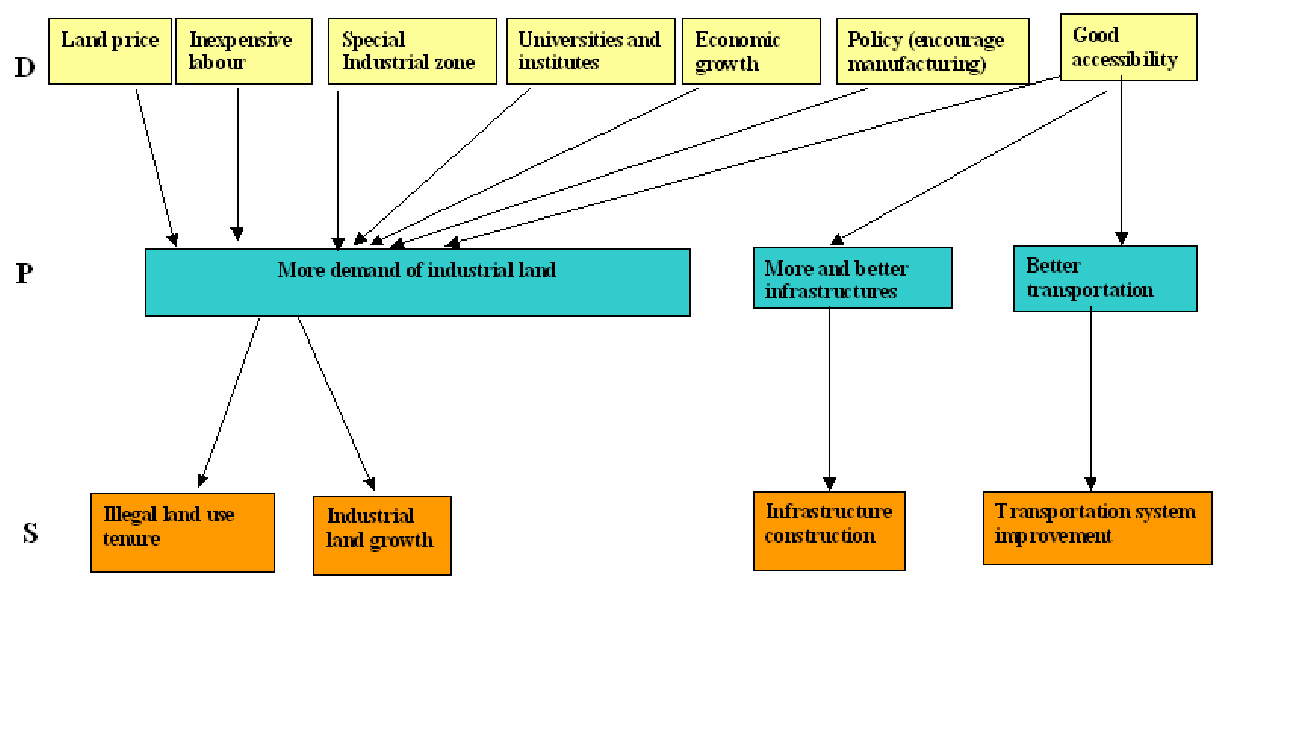


Figure 4.2The DPSIR model of industrial land

- Economic growth

Economic growth is the inherent trigger that sets off the employment-led peri-urbanization in the Hongshan area, the vicinity of wuhan city. Hongshan District has been granted one of ten powerful districts/countries in Hubei province for seriate several years. This area is experiencing a prosperous period of economic development. To a certain extent, which is illustrated by the nearly 15 percent of its GDP growth per year. Not only the top-down flagship projects but also the flourishing township and village enterprises may contribute to this economic growth. But not like the coastal areas of China where TVE (Township and village enterprise) clusters have shown their excellent economic performance, state-owned and collectively-owned enterprises still have a high proportion. Moreover vast majority of Foreign Direct Investment is flowing into this area. Such eminent economic stage certainly retains existing enterprises and attracts more industrial activities coming.

- Accessibility

The availability of basic municipal facilities will have a significant impact on the location of industrial land. Easy access to water lines, sewers, electric power, telecommunication and other facilities is essential to the development of enterprises. Especially in the case study area, the fringe area of wuhan city, many basic facilities are still being built up and the existing ones are limited, so a preference to near these facilities will exist to direct the location of industrial land.

In literature, to near the main roads will mean the good accessibility to the markets and save much transportation cost. These roads are acting as bridges that connect the urban core, urban fringe and rural area. Through it, enterprises are able to get kinds of flows. To enter into the domestic markets, train rail is an efficient way to move raw and processed materials, products and so on.

- Universities and institutes

Hi-tech manufacturing is the essential industry of Hongshan area. As the second largest domestic scientific, educational and intellectual concentrated area, many universities and state-level scientific research units are located in Hongshan District. These universities or scientific institutes supply a good R&D flat, which greatly improve the innovation of hi-tech enterprises. So accessibility to these flats is also a driving factor to the growing industrial land.

- Existing Special Industrial zone

The state-level Wuhan East Lake Hi-and –new-tech Development Zone is established by the Wuhan municipal government and situated in the Hongshan area. Scale economic and aggregation economic will demand more industrial land around this zone. Just as Webster (2002) referred that cluster dynamics can lead to considerable dynamism, once initial advantage has been developed.

- Policy

The demand for the large industrial land is often reinforced and strengthened by Wuhan municipal governments' decentralization policies. In the documents and mater plan, the construction of public infrastructures in case area is greatly encouraged.

Reviewed from the Ninth Five-year Plan of Hongshan (Hongshan Development Planning Committee, 1996), the adjustment of industry structure is the key word of its industry development. Hongshan government try to improve the proportion of secondary industry. Corresponding to this policy, industry activities are greatly welcomed. It may be clearer from such an example that those who introduces manufacturing, hi-tech industry investments and who introduces the world 500 investments, will be rewarded of 5%o according to "Reward scheme introducing foreign capital to

Hongshan District". Other relatively incentive policy packages are usually in the form of beneficial tariff and tax to investors for a specified period of time, subjected to certain conditions.

- Good environment

To the hi-tech enterprises, they do not need to consider the energy sources like the tradition industry sectors. Thus they would prefer to choose their sites surrounded by the good environment just like the "silicon valley in USA".

- Land price

Usually low land price means low cost. In the economic activities, max- profit is always the principal discipline. But it is not an absolute concept especially when the investment cost is too high. So whether positive or negative effects caused by land price can be confirmed by CLUE model.

- Inexpensive labour

Same as the vicinity of other cities in china, more and more surplus rural labours are generated with the urbanization in the Hongshan area. In the case area, there are about 110,000 rural laborers. Local labour is employed in manufacturing enterprises and township and village enterprises, where job entry requirements are relatively low enough. Meanwhile in the premise of good accessibility, numbers of highly skilled domestic laid-off workers unemployed from the national enterprises come to the urban fringe attracted by the wages. All of these result in the low labour price, which is also an inarguable drive factor of the industrial land growth.

What are the pressure and the state?

Attributing to above driving factors, the case area is bearing some pressures. More public facilities and better transportation system are required. Industrial pollution threatens the environment. Certainly more industrial land plots are needed.

As the results of these pressures, industrial land is certainly growing. By-products of this growth, illegal land tenure is happening at the same time. Correspondingly, the case area are suffering such problems that infrastructure lagging, partly transportation congestion and environment deterioration.

4.4.1.2. Residential land DPSIR

Residential land in Hongshan is also experiencing a quick development. Figure 4-3 graphically outline the interaction. The factors are described below.

What drives the residential land development?

- Economic growth

As the direct result of the economic growth, people's income is improved greatly in Hongshan. The urban population income is increasing 10 percent every year, while rural 8 percent Although the house price is increasing at the same time, the supply of houses seems not to fulfil the local people's demand. Economic growth increases the people's probability to buy houses.

❖ Population growth

Land use change is often seen in the light of its high population pressure. Hongshan's population as described above is risen quickly. With a rising demand for houses, as a consequence of this population growth, it is essential to develop more residential land.

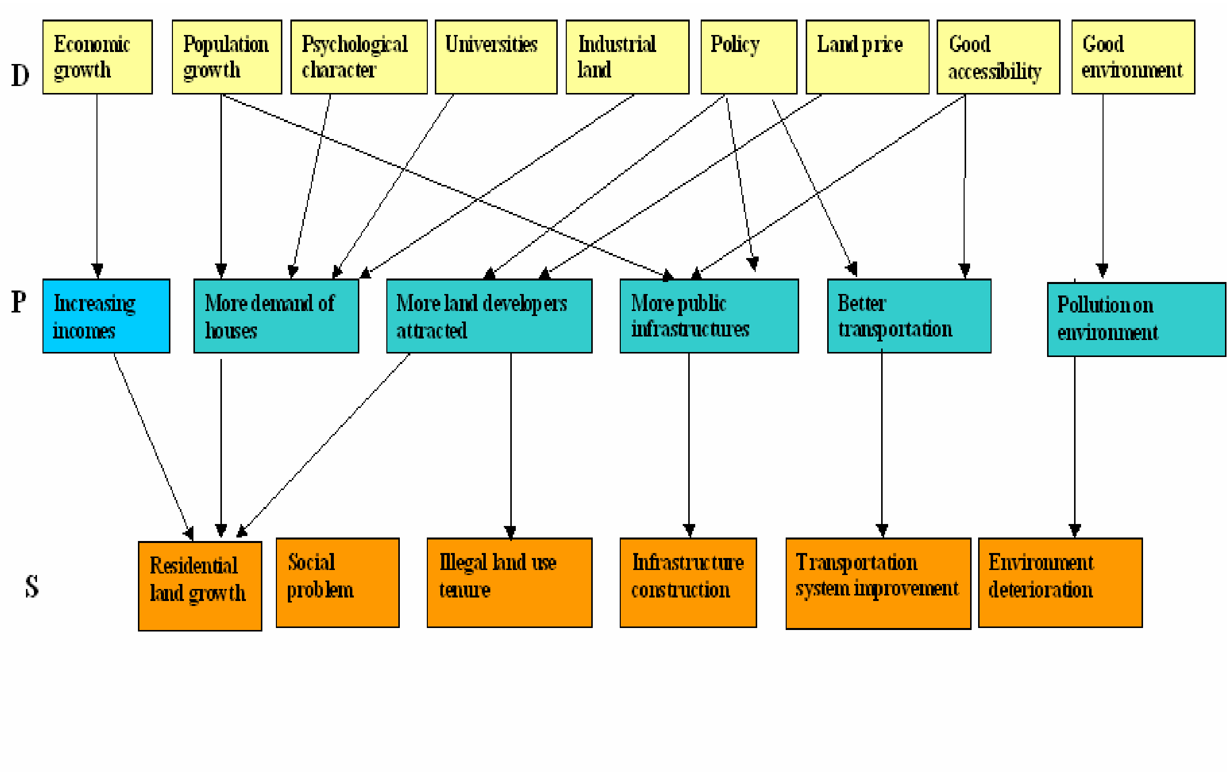


Figure 4.3 the DPSIR model of residential land

❖ Psychological character

In China, consumption pattern is special. Most of traditional Chinese would consider purchasing a family house in the city as the most important thing of one's life. Before owning the adequate capacity of affording a house, they will not spend much money on other things. Some changes are happening in these years. People will not scream for a house in the city. A house in the fringe of city is also satisfied. Hence, the changed psychological character should be included in the factors.

❖ Special Industrial zone

Discussed above, Chinese urban fringe is mostly led by the industry. There is a state level Industry Park and several small-scale Special Industrial Zones in Hongshan area. These zones attracted more and more manufacture factories. Vast numbers of jobs are filled not only by local people but also migrants. In view of the poor transportation system, most of these 'floating population' would like to live near their factories. Thus, the Industrial Zone is an important driver stimulating the residential land development.

- Policy

The Tenth Five-year Plan of Hongshan referred that the development of real estate are greatly encouraged (Hongshan Development Planning Committee, 2001). To improve the per-capita housing area, a number of high quality residential zones are required to be built. Since the reform of housing system, the policy-based house is abolished and capitalization of housing distribution takes its place. Furthermore, individual housing loan is encouraged by the low interest and zero-yuan first payment. Such policies will greatly influence the development of residential land.

- Low land price

From the view of real estate developer, land price is an essential indicator to decide a real estate activity. Located in the fringe, the land price of Hongshan area is lower. So land price is also a factor affecting the residential land development.

- Good Accessibility

In terms of spatial indicators, households focus on site and situation characteristics of location. Level of supply of public service, good access to municipal facilities and proximity to the built-up area and minor centres of city are the examples of those characteristics.

- Good environment

Hongshan District has been recognized as one of the first “Comfortably off Districts/Counties” in out province. There are two famous scenery sits in this area. For the households, natural amenity will certainly please households, far away from the noise, polluted air and polluted water.

What are the pressure and the state?

These factors drive the development of residential land. Meanwhile, some pressures are also brought. More houses are demanded. More public infrastructure and better transportation are also required. With the highly increased residential refuse, environment has to be a pressure of pollution everywhere.

Correspondingly, residential land is increased to fulfill the great demand. On the other hand, some illegal land tenure is emerging inevitably for varies of land developers are attracted. Infrastructure backlogs, transportation congestion and environment deterioration are also problems of the case area.

4.4.1.3. Public facility land DPSIR

In this section, the relationship between the causes and effects of the development of public facility land will be investigated. Figure 4-4 has shown this relationship.

What drives the public facility land development?

- Economic growth

The booming economic growth improves individuals’ living standard. The luxurious consumer pattern is happening among the young Chinese people. They want to enjoy better goods and comfortable public service. On the other hand, the good economic environment enables government to give more investment on the development of pubic facility.

❖ Population growth

The rapid population growth results in the great need of public facility. Every kind of facility has its certain service capacity and coverage. So the high population pressure also seems to drive the public facility land development.

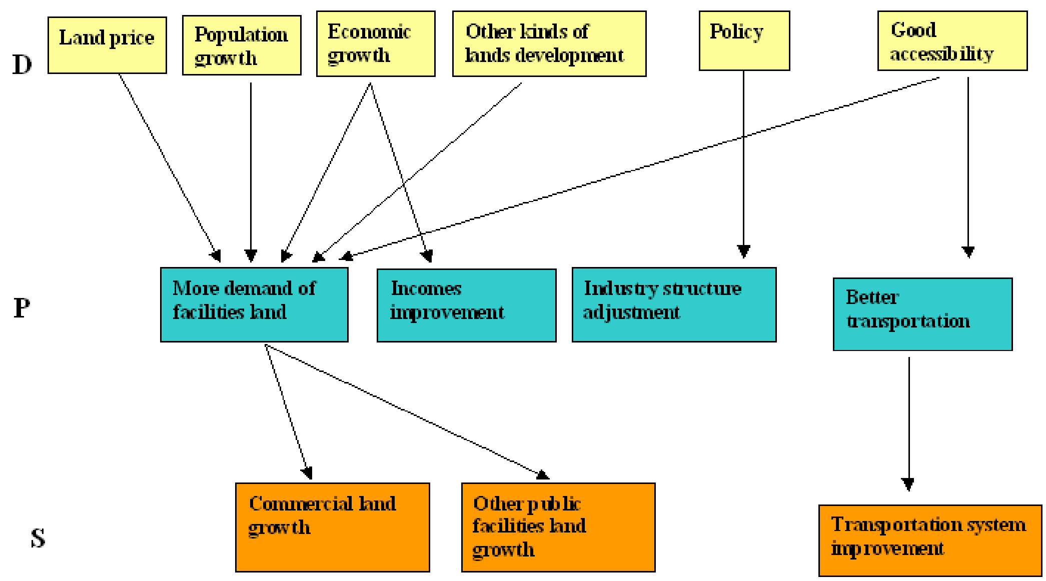


Figure 4.4 The DPSIR model of public facility

❖ Other kinds of lands development

The public facility affects the development of residential land, and reciprocally the residential land influences the public facility. In Hongshan area, more public facility and commercial centres are emerging around the residential zones. In the Industrial Zone, the demand for the municipal facilities and trade markets is more significant.

❖ Policy

Tertiary industry (is greatly encouraged in the Hongshan District, indicated from The Tenth Five-year Plan of Hongshan and the Tenth Five-year Plan of Hongshan's tertiary industry. It is increasing 23.5 % per year. The contribution of this sector to GDP increases from 35．1%of 1995 to 43．6% of 2000. Furthermore, this increasing trend will be intensified by the government's encourage. From the physical and functional dimension, this development is presented by the development of public facility land.

❖ Good accessibility

Proximity to the main roads and centres will help the public facility have larger service coverage. At the same time, the interval with the existing public facility should be paid attention to achieve the optimal allocation.

❖ Low land price

Low land price is a main criterion for the land developer to develop a parcel of commercial land. However, it seems make no sense to the development of municipal facilities, because all these projects were invested by the government.

What are the pressure and the state?

These assumed factors behind the public facility result in the relative pressures. Firstly, facility land shows its high scarcity. Policy on the adjustment of industry structure pays more attention the tertiary industry. Transportation system is also need to be improved. Concern on the state, public facility land is increasing dramatically. Meanwhile, the case area shows its congestion of transportation

4.4.1.4. Green land DPSIR

In this section, the driving factors affecting the development of green land will be found out. The interactions between these behaviours are outlined by figure 4-5. The green land DPSIR seems to be a little simpler than other ones.

What drives the green land development?

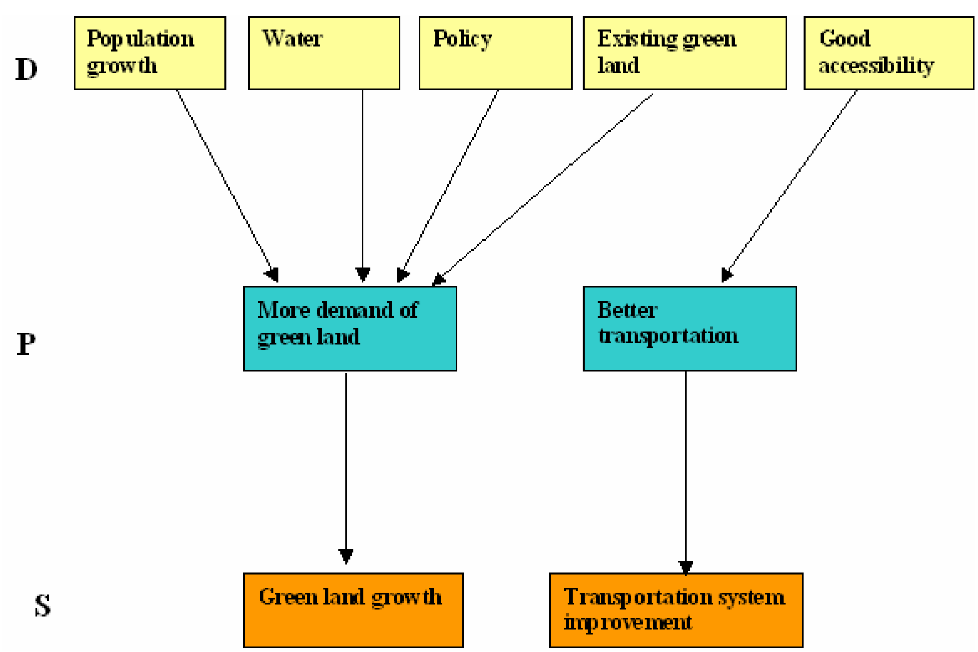


Figure 4.5 the DPSIR model for green land

❖ Population growth

Just like the public facility, the demand for the green land is increasing associated with the rapid population growth. Open space is very important to the people's living quality.

❖ Water

There are many lakes in the Hongshan area. Proximity to these lakes will provide the green land more comfortably and attractively. Green land is an artificial 'nature' for people. Preference to the water seems to be one character of human. It can be proved with vast numbers of classic square and parks.

❖ Existing green land

Green land also has the service coverage. So the green lands will influence each other.

❖ Policy

In Wuhan's master plan and government's report, to improve the green land area is always emphasised according to the objective of built a garden city.

❖ Good accessibility

Easy access to the green land is important for local people. For them, travel time should be spent on the trip not on the daily leisure.

What are the pressure and the state?

More green land and better transportation condition are required attributed to these factors.

As the consequence of such pressure, green land is experiencing an increasing process, and same situation for the transportation.

4.5. The representation of factors in CLUE model

The possible underlying factors has been identifies in the above section using DPSIR model. However, they are still too general for the regression model. A selection of some of the factors influencing and controlling land use change in case study area is given in the following table (table 4-1).

Table 4.2 Driving factors of spatially explicit land use change

Land use change drivers	**Representation as variables**	**Descriptive**	**Source**
Population growth	DEN	Population density	Census state
Land price	RLP	Residential land price	Wuhan government
Land price	ILP	Industrial land price	Wuhan government

Land price	CLP	Commercial land price	Wuhan government
Water	DISW	Distance to water	1996 land use map
Existing green land	DISG	Distance to existing green land	1996 land use map
Public facility	DISP	Distance to existing public facility	1996 land use map
Railway	DISR	Distance to railway	1996 land use map
Accessibility	DISDA	Distance to developed area	1996 land use map 1994 road net map
Accessibility	DISOC	Distance to minor centre	1996 land use map 1994 road net map
Accessibility	DISMR	Distance to main road	1994 road net map
Accessibility	DISOR	Distance to minor road	1994 road net map
Industry Zone	DISIZ	Distance to industry zone	1996 land use map
Utility	DISU	Distance to municipal utility	1996 land use map

This is far from exhaustive list of actual factors driving land use change. This can be explained by two reasons: one is the difficulty expression of some factors such as psychological characters; the other is the poor data infrastructure at the district scale in Chinese cities such as labour price and even GDP.

In this research, population density is used to represent the population growth. For the different types of land use, the land value is different in the same location. Three kinds of land price are generated according the document of Wuhan's government.

There is no universal standard of road classification as it is determined by quite a number of indefinite factors like adjacent land use, traffic volume, road width, and construction materials. It is the same for the definition of city sub-centres. The connection with city major centre can be calculated into the access to roads and the developed area. In order to reduce the uncertainty in classification, only two classed (major and minor) are identified. The determination of classification is principally based on the local knowledge available from master and transportation planning schemes, and tourism maps. Some interviews with local planner are also necessary.

In the case study area, water body takes a major percentage as seen from the land use map. Theoretically water bodies should be completely excluded from land cover. But in this case study, many small-scale water bodies are 'eaten' in the period 1996-2002 without high protection. So only those large-scale water bodies are reserved. A general procedure can be designed for defining this layer: extracting water body from land cover layer; query areas > 15ha, convert to a special layer.

Proximity is a prime cause of land use change. Here the proximity variables measure the direct access to city centers, minor centers, major road, minor road, public facility, water and universities. The physical indicators equip any site with necessary development potential.

Because of the logistic regression's sensitivity to the data transformation, it is necessary to standardize these factors. Here all variables are transformed into the range from 0 to 1. This measurement can be completed by the maxim standardization using ILWIS 3.2.

4.6. Model developed for the case areas

In this section, the components of CLUE-HS will be formulated.

4.6.1. General model framework

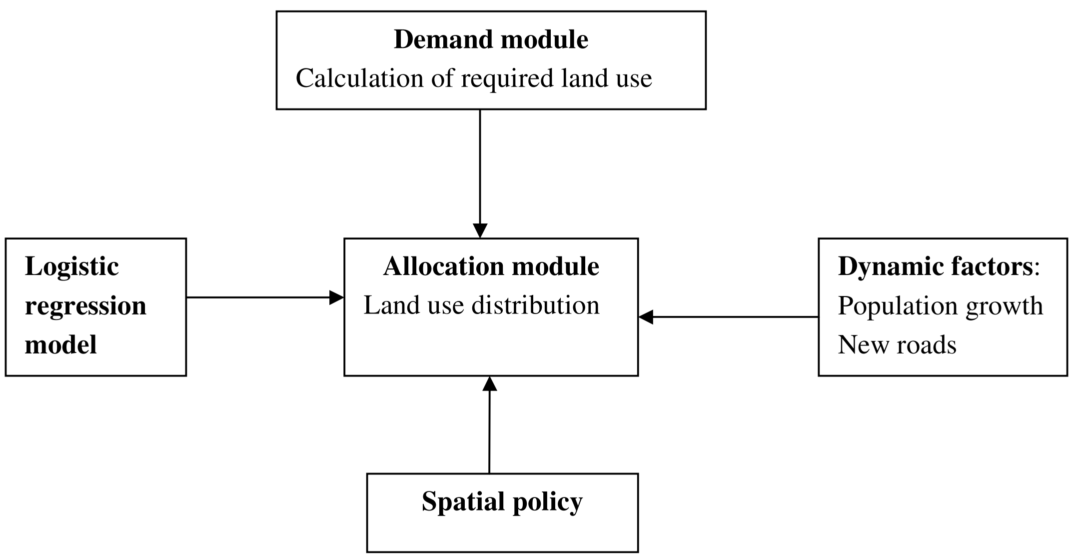


Figure 4.6 General structure of the CLUE-HS modelling framework for Hongshan

Fig.6 gives an overview of the main components of the CLUE-HS modelling framework. The demand module defines scenarios for changes in demand for different land use types. These scenarios are based on the previous study on the case study area. Dynamic factors are taking into account population growth and new constructed roads. Spatial policy designates the special areas not involved in the land use allocation with respect to the area restriction module of CLUE.

4.6.2. The demand module

The scenario used for the simulations is a baseline scenario of which the demands for the different land use types as presented in table 4-2.

Table 4.3 Baseline scenarios for CLUE-HS simulations

Land use types	**Area in 1996 (hectares)**	**Yearly change**
Residential land	748	3.5%

Agricultural land	13345	-0.5%
Water	8727	1%
Industrial land	764	-0.8%
Public facility	2580	2.1%
Transportation	652	-
Green land	555	2.1%

These demands are based on the trend of land use change for the period 1996-2002 and the predicted land use demand derived from the master plan 1996-2020. The growth rate to 2010 is assumed to the average of them.

4.6.3. Statistical regression

Table 4-1 has given an overview of demographic, socio-economic and proximity variables evaluated in the analysis of the Hongshan area. But different land use types have different explanatory variables. The equations below show respectively the relationship between the land use and influential factors.

$$P\ (\text{residential land}) = \beta_0 + \beta_1 DEN + \beta_2 RLP + \beta_3 DISW + \beta_5 DISMR + \beta_6 DISIZ + \beta_7 DISG + \beta_8 DISOR + \beta_9 DISDA + \beta_{10} DISOC + \beta_{11} DISP$$

$$P\ (\text{green land}) = \beta_0 + \beta_1 DEN + \beta_2 DISW + \beta_3 DISMR + \beta_4 DISG + \beta_5 DISOR$$

$$P\ (\text{industrial land}) = \beta_0 + \beta_1 DISMR + \beta_2 DISIZ + \beta_3 DISU + \beta 4ILP + \beta_5 DISOR + \beta_6 DISDA + \beta_7 DISOC + \beta_8 DISP$$

$$P\ (\text{public facility}) = \beta_0 + \beta_1 DEN + \beta_2 DISMR + \beta_3 DISIZ + \beta_4 CLP + \beta_5 DISOR + \beta_6 DISDA + \beta_7 DISOC + \beta_8 DISP$$

Where P is the probability of a grid cell for the occurrence of the considered land-use type and β imply the contribution of each explanatory variable in P. A positive sign means that the explanatory variable will help to increase the probability of change and a negative sign means the opposite effect.

However, not in all situations all of these variables will add a significant contribution to the explanation of the land use distribution. Therefore, a stepwise regression procedure is used to straightforwardly select variables with a significant contribution. And the next chapter will report on the results of this analysis.

4.6.4. Restricted area

CLUE model is able to simulate connectivity between locations originating from feedbacks over a higher level of organization (Verburg 2002). This will be illustrated by simulating the hypothetical protection of part of agricultural land or water bodies. In Hongshan area, there are a historic protected area, a preventing flood zone and a protected agriculture area. Theoretically, these protected should be excluded from the allocation process. Relative scenarios can be generated if these areas are not protected.

4.6.5. Conclusion

In this chapter, the influencing factors are identified with the help of DPSIR model. The possible factors are represented based on the available data. The concept model of CLUE is developed for the case study area. Also the demand module and area restriction of CLUE model are defined for the case study area.

5. Simulation of land use patterns (in the case study area)

5.1. Introduction

In this chapter, the implement of CLUE-HS model is presented. Software implementation, logistic regression modelling details will be considered. Spatial autocorrelation and model sensitivity are realized. At last, some possible future situations based on the scenarios are discussed.

5.2. Data issues

Land use data of 1996 were derived from the 1:25000 land use map of Hongshan District (1996), which was already in digital format (CAD format) and is produced by the Wuhan Bureau of Urban Planning and Land Administration through the support of local government and considerable fieldwork. This is considered to have the best accuracy for this research, so municipal facility map, railway map, minor centre map, developed area map and conserved area map are all derived from this map. Unfortunately a time series of high resolution land use map is not available because the fringe area of Wuhan is not well covered by the existing remotely sensed images. Land use data of 2002 was manually digitised from the land use map of Wuhan (2002), which was provided in a JPG format by the Wuhan Urban Planning Institute. Though the resolution of this map is not high, the trend of land use change is able to be observed.

Population distribution map was derived from the Wuhan Population Census of 1996-2002. The census was obtained based on administrative units (townships or blocks). So it is assumed that the average population density is same in the same administrative unit despite that some townships are spatially divided into several regions.

Road data were digitised from the land use map and corrected with the tourist maps and planning schemes. The road classification has been discussed in section 4-4.

The data of Industry Zone was digitised from the planning map of East Lake Industry Zone provided by the Wuhan East Lake Hi-and –new-tech Development Zone Office.

In order to account for the accessibility, the distance to these relative sites was calculated through a standard distance operation using the centres of grid cells as a reference points. This spatial analysis can be implemented by the ‘find distance’ function of Arc View 3.2a.

All GIS data are brought together in an equal-area projection and converted into a common spatial resolution of 100 m. This resolution was largely determined by the nature of variables and the size of the case study area.

5.3. Statistical analysis of land use drivers

5.3.1. Spatial sampling procedure

CLUE modelling is based on the result of spatial logistic regression, which involves substantial amounts of spatial variables. This statistical method assumes that the data to be statistically independent and identically distributed (Overmars, de Koning and Veldkamp, 2003). But, spatial land use data have the tendency to be dependent, a phenomenon known as spatial autocorrelation, which can be defined as the property of random variables to take values over distance that are more similar or less similar than expected for randomly associated pairs of observations, due to geographic proximity.

And the presence of spatial autocorrelation in the spatial regression procedure has been tested in several cases (Overmars, de Koning and Veldkamp, 2003; Cheng, 2003) and the coincident conclusion is that the regression coefficient and significance of the contribution of individual variables are sensitive for the spatial autocorrelation. Ignoring these issues will lead to unreliable parameter estimation or inefficient estimates and false conclusions.

Hence, a couple of steps are taken to minimise the spatial autocorrelation before executing the multiple regression analysis.

First step is to detect the spatial autocorrelation of variables in the case study area. Moran's I index can be used to identify and quantify spatial dependency (spatial autocorrelation) in spatially explicit land use studies (Overmars, de Koning and Veldkamp, 2003). It uses values between 0 to 1 to present the degree of linear spatial association between observed locations and a weighted average of the corresponding neighbouring sites. In this study, the Moran's I index shows high correlation (above 0.9) for most of independent variables.
This indicates that the high spatial autocorrelation may obscure the results of a regression analysis.

A frequently adopted alternative to deal with the spatial dependence is to design a spatial sampling scheme to expand the distance interval between the sample sites. It will result in a much a smaller size of sample, which will lose certain information. However, logistic regression is based on a large sample of asymptotic normality, which means the result may not be reliable when the sample size is small. It is a conflict in the regression: the removal of spatial dependence and the large size of the sample. Consequently, a 'suitable' sample size is better to balance them.

Spatial random sampling is used in this study to reduce the size of samples (in the case area 23636 pixels) and remove the spatial auto-correlation. When a 7% random sampling is reached, Moran's I index significantly for all independent variables (about 0.6). Its total size is 18997 pixels. Moran's I index and random sampling is implemented under the grid module of Arc Info 8.0.

5.3.2. Logistic regression results and interpretation

The large sets of variables explained in the conceptual model were input into the logistic regression model.

The most important land use drivers for the four land use types were selected by means of stepwise regression via the SPSS 12.0 package, using the 0.01 significance criterion for each independent variable.

Table 5-1 gives the sight of the correlations found between a number of explanatory variables and kinds of land use in 1996. The positive values mean that the probability will increase upon an increase in the value of the independent variables. The negative values indicate a decrease in probability upon an increase upon an increase in the independent variables. The ROC values indicate whether the spatial pattern of land use types can be reasonably explained by the independent variables.

Table 5.1 Logistic regression result

Variables	New residential land	New green land	New industry land	New public facility
Steps of regression	6	6	6	3
Sample size	18997	18997	18997	18997
DEN	-0.717	-1.040	-[b]	**
RLP	**	-[b]	-[b]	-[b]
ILP	-[b]	-[b]	-1.365	-[b]
CLP	-[b]	-[b]	-[b]	1.016
DISW	**	-5.755	-[b]	-[b]
DISG	**	14.739	-[b]	-[b]
DISR	2.756	-[b]	**	-[b]
DISP	6.333	-[b]	-[b]	**
DISDA	**	-[b]	**	**
DISOC	**	-[b]	-6.915	**
DISMR	-8.711	-10.024	-20.771	-5.697
DISOR	5.793	**	12.095	4.185
DISIZ	**	-[b]	8.731	**
DISU	-[b]	-[b]	2.123	-[b]
Constant	-3.095	-3.343	-2.512	-2.390
ROC[a]	0.734	0.728	0.710	0.606

**: Non-statistically significant;
-[b]: Not selected;
ROC[a]: relative operating characteristic statistic.

This section highlights these main results of the spatial logistic regression. The results for all the four dependent variables will be interpreted. To classify the result, the equations with the significant factors will be presented for every type of land use based on table 5-3.

- Residential land

P (residential land) = -3.095 – 0.717[DEN] + 2.756[DISR] + 6.333[DISP] – 8.711[DISMR] + 5.793[DISOR] (1)

Equation 1 gives the variables with the high correlations to the relative cover of a grid cell with residential land. The major determinants with negative effect are the distance to the main road (the nearer, the clearer) and population density (the lower, the better). Distance to railway, distance to public facility and distance to minor road (the further, the better) present their strong positive effects. A remarkable correlation with the main road and distance from the minor road indicate that householders in this urban fringe area have a high communication with the other parts of the city because of their work places. Theoretically proximity to the public facility is preferable. However the situation seems to be different in this case area, a fringe area of Wuhan. It could be explained by its spatial location in the vicinity of city area. No data splitting up the large public facility category into different species are available. But many special facilities such as large-scale municipal facilities, special hospitals for the treatment of tuberculosis and psychosis and crematories are located in this fringe area. Proximity to the railway apparently has a negative influence on the preference for the residential land because of noise.

- Green land

P (green land) = -3.343 – 1. 040[DEN] – 5.755[DISW] + 14.739[DISG] – 10.024 [DISMR] (2)

Equation 2 gives the estimated coefficients for the logistic regression describing the land use pattern of green land. Distance to main roads, population density and distance to water are dominating factors with negative impact. While a negative relation for the new green land is found with the distance to existing land. Green land is clearly associated with the proximity to the main roads and low population density. It could be understandable because these parks or open space will service the people of the whole city and occupy large-scale land. The service coverage can be used to explain the association with the existing green land. Proximity to the water needs no future explanation.

- Industrial land

P (industrial land) = -2.512 – 1.365[ILP] – 6.915[DISOC] – 20.771[DISMR] + 12.095[DISOR] + 8.731[DISIZ] + 2.123[DISU] (3)

Equation 3 summaries the estimated coefficients of the logistic regression result for the industrial land. In order, the strong negative determinants are the distance to the main roads, distance to the minor center and industrial land price. While the positive effects are associated with the distance to minor roads, distance to the industry zone and distance to the municipal facility. The proximity to the industry zone has been expected to attract the new industry land but this logistic regression result indicates that the proximity to the main roads is more preferable for the industrial land. Proximity to the minor centre and low industrial land price is relatively important to a lesser extent. Because the industrial land in this study area is mostly occupied by the hi-tech enterprises, regional communication is more significant than local one indicated by the negative effect of the minor road and municipal facility is not as reliable for these hi-tech industry as the traditional industry.

- Public facility

P (public facility) = -2.390 + 1.016[CLP] – 5.697[DISMR] + 4.185[DISOR] (4)

Equation 4 shows the relationship between location factors and public facility. Distance to main roads again is the significant determinant with its negative effect. While land price and distance to minor road shows their positive effect. The relationship with the main road and minor road indicate that regional flows are essential for the public facility. Concerned on the land price, the lower price is usually considered as the better. But when the possible investment cost on the land with low price is too high, the higher will be better. In this study, it is at such situation.

Through the regression result, it is found that proximity to main road is significant determinant for all four land use change studied. It strengths that the development of urban fringe in other words urban expansion will preferably happen along the transportation corridor.

5.3.3. Probability maps generated from the regression result

Based on the regression result, probability maps can be generated by CLUE-HS model for every type of land use. These maps (figures 5-1) are useful to indicate whether the hypothesis for the driving factors of each land use type is right. Through these maps, the potential distribution for kinds of land use is spatially explicit.

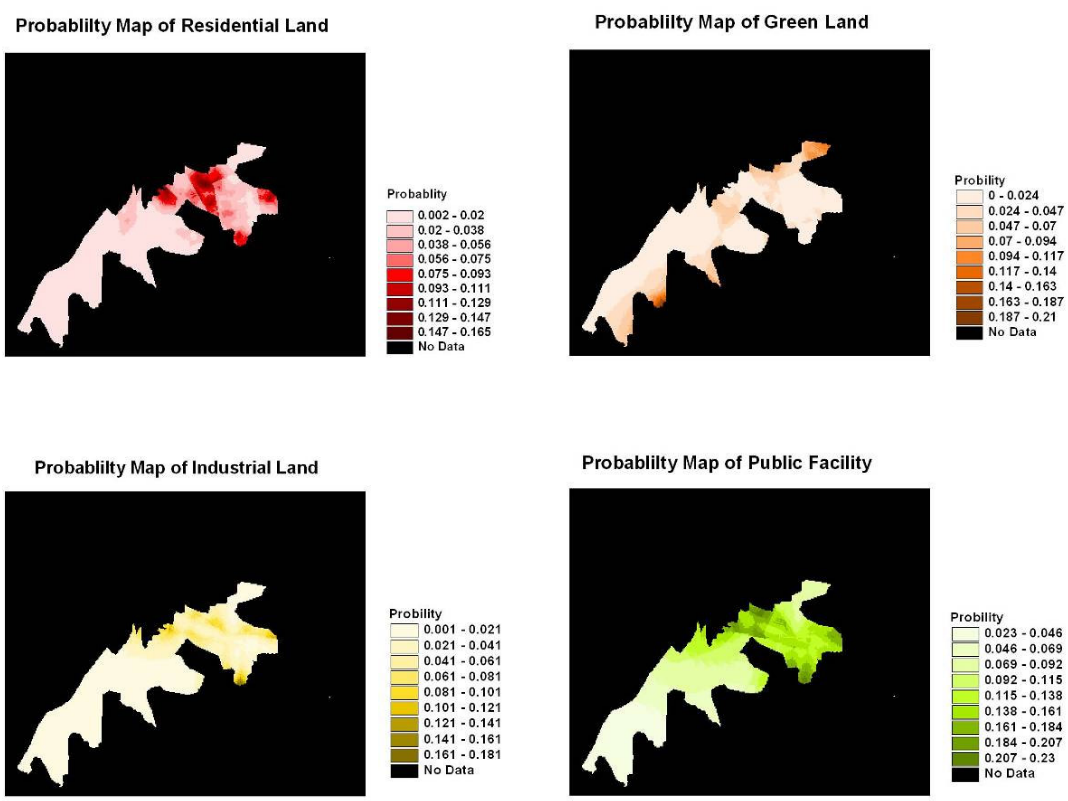


Figure 5.1 Probability maps

5.3.4. Evaluation of the logistic regression

To evaluate the goodness of fit of a logistic regression model, a quantitative measurement called the relative operating characteristic (ROC) is used. The ROC technique applies to any model that predicts a homogenous category in each grid cell (Pontius and Schneider, 2001).

Figure 5-2 graphically presents the general flow of this method to validate the logistic regression model. Every land use type combined with their respective factors maps generates each probability map through the logistic regression model. The probability map is sliced into several percentile groups on the basis of the probability values, for example 10 deciles. The next step is to overlay these scenarios from different groups with the reality land use map and then a tabular result will show the proportion of grid cells of each probability group that are categorized as change versus non-change in reality.

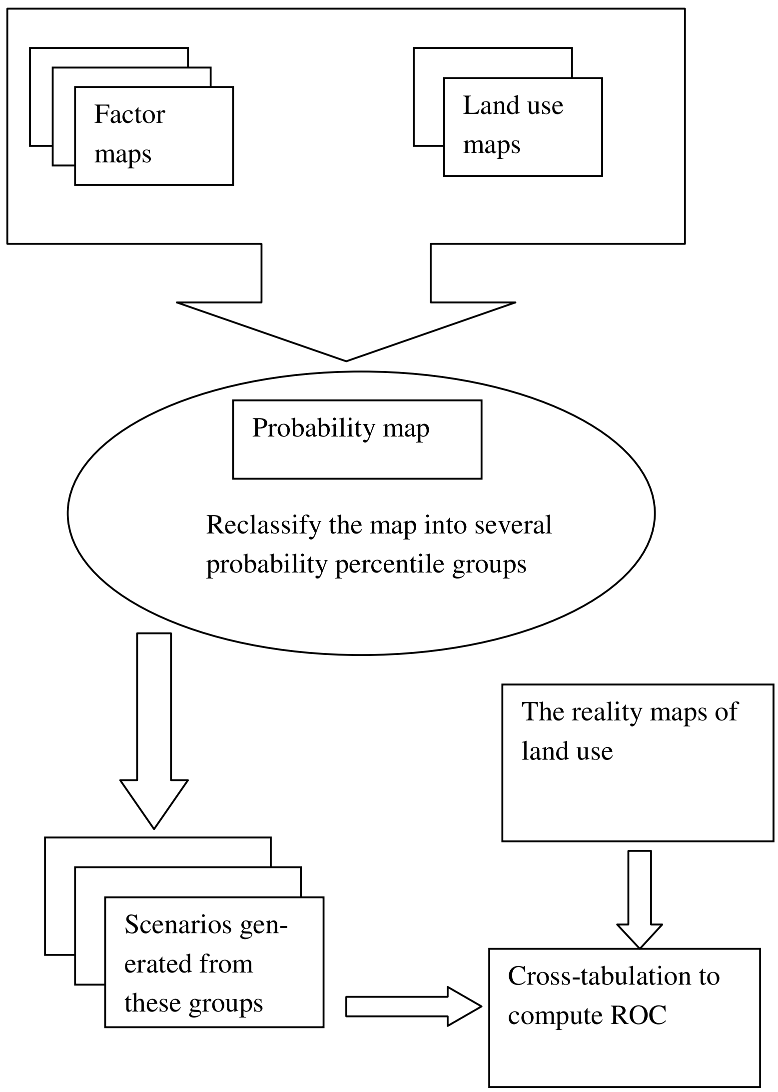


Figure 5.2 Flow of ROC method to validate the logistic regression model

If a grid cell is simulated as change in a scenario, it is a 'positive'. Therefore a 'true-positive' is a cell that is categorized as change in both reality and the modelled scenario. A 'false-positive' is a cell that is categorized as non-change in reality and as change in the modelled scenario. Figure 5-3 illustrates the definition of the ROC. In this figure, the rate of true-positive on the vertical axis is versus the rate of false-positives on the horizontal axis for each of the scenarios. Each scenario corresponds to a point in the plotted space.

The ROC statistic is the area under the curve that connects the plotted points. Equation 5 uses integral calculus's trapezoidal rule to compute the area, where x is the rate of false positives for scenarios i, y the rate of true positives for scenario i and n the number of probability groups:

$$\text{Area under curve} = \sum_{i=1}^{n} [x_{i+1} - x_i][y_i + y_{i+1} - y_i /2] \qquad (5)$$

If the sequence of the simulated values matches perfectly the sequence of real land use change, then ROC is equal to 1.

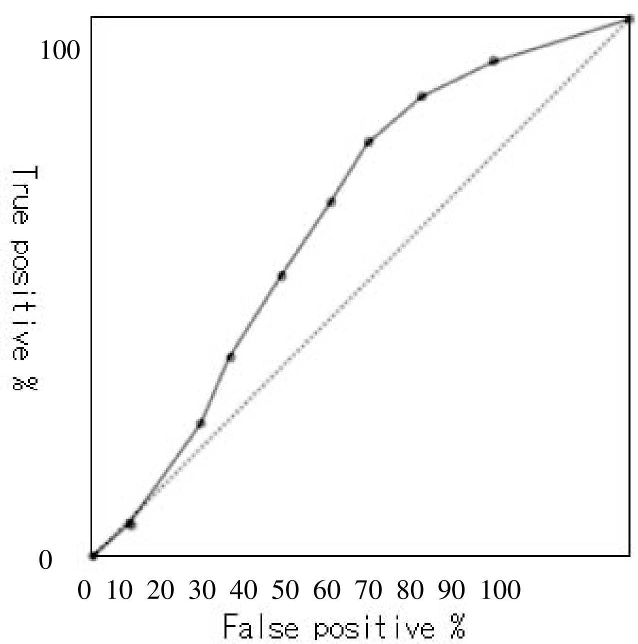
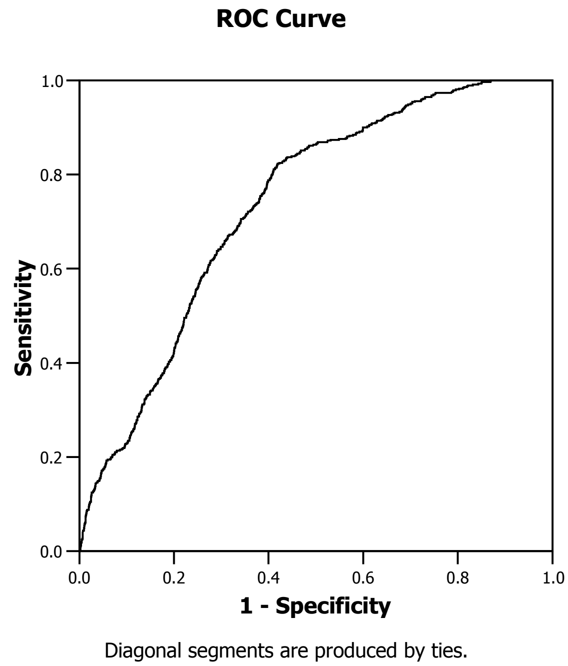


Figure 5.3 ROC curve

In literature, any ROC above 0.5 is 'good' and above 0.65 is better (Pontius and Schneider, 2001). Apparently the closer this value is to 1, the better is the fit of the logistic regression model. This ROC method can be employed through the ROC curve function of SPSS based on the spatial dependent variables and independent factors after logistic regression.



Area Under the Curve Test Result Variable(s): Predicted probability

Area
.734

Figure 5.4 ROC curve of the regression for residential land

The above figure is the ROC curve which shows the validation of regression result for the residential land in term of the logistic regression model for the case study area. The area value (0.734) presents its ROC value which is ‘good’ value above 0.5 according to above discussion. Other land’s ROC curve can be seen in the appendix. From table 5-1 ROC values for all land use type are satisfied except for the public facility. It may be explained by the data problem which combined varieties of land use types. So some factors are not identified well.

5.4. Parameters settings

5.4.1. Implement platform

Because of the differences in data representation and other features that are typical for regional application, the CLUE model can not directly be applied at the regional scale. CLUE-S (the Conversion of Land Use and its Effects at Small regional extent) is specifically developed for the spatially explicit simulation of land use change based on an empirical analysis of location suitability combined with the dynamic simulation of competition and interactions between the spatial and temporal dynamics of land use systems (Verburg, P.H., et al., 2002).

Correspondingly, the latest vision of CLUE model implement platform developed by the CLUE group in 2003, CLUE-S Version 2.3 (shown as figure 5-5) was implemented in this case study. Before running this CLUE software, all GIS rater data were converted into ASCII files. Demand scenario which calculates required land in different years was represented in a txt file. The logistic regression result can be input into the model at the interface.

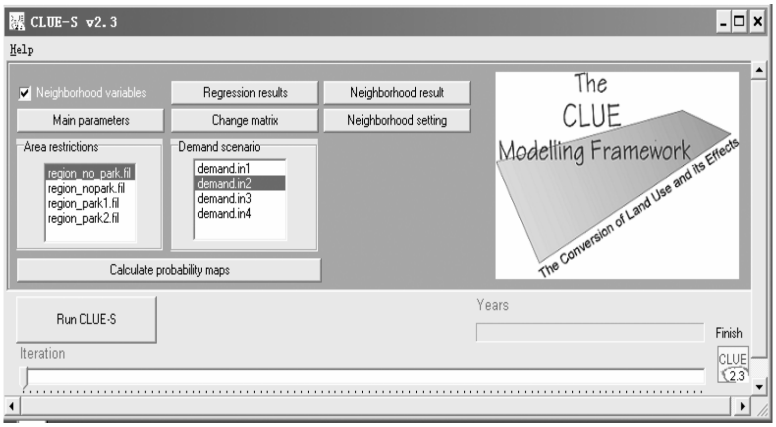


Figure 5.5 The interface of CLUE-S vision 2.3

5.4.2. Land use type specific conversion settings

In the CLUE-S implement, land use type specific conversion settings determine the temporal dynamics of the simulations. Two sets of parameters are needed to characterize the individual land use types: conversion elasticity and land use transition sequences.

The first parameter set, the conversion elasticity is related to the reversibility of land use change. Land use type with high capital investment will not easily be converted in other uses as long as there is sufficient demand. Other land use types easily shift location when the location becomes more suitable. Therefore, for each land use type a value needs to be specified that represents the relative elasticity to change, ranging from 0 (easy conversion) to 1 (irreversible change). In this study, the value for residential land is 0.8 because to remove householder's old houses is a very difficult thing in China. The value of 0.5 is set for water. Though the water bodies in the case area is easily changed into other land use based on the observed behavior, local government is realizing its ecological problem and try to make some measurement to restrict these develop activities. Similarly, the green land is often threatened by the other land types' development but in a better situation than water. So a value of 0.6 is specified for it. In the recent past, some public facilities were converted into residential land or industrial land. 0.6 is given to this land. For the industry land, it is difficulty to change if there is no policy about the relocation of industry. While the agricultural land often makes place for urban development especially in this fringe area. Hence the value for the agricultural land is set to 0.

The second set of land use type characteristic that needs to be specified are the land use type specific conversion settings and their temporal characteristics. These settings are specified in a conversion matrix. This matrix can define: to what other land use types the present land use type can be converted or not; in which regions a specific conversion is allowed to occur and in which regions it is not allowed; how many years the land use type at a location should remain the same before it can change into another land use type; and the maximum number of years that a land use type can remain the same. In this case study, all interactions between varieties of land use except railway are allowed in the whole time steps.

Table 5.2 Land use conversion matrix

Future land use → / Present Land use ↓	Residential land	Agricul-tural land	Water	Industrial land	Public facility	Railway	Green land
Residential land	1	1	1	1	1	0	1
Agricultural land	1	1	1	1	1	0	1
Water	1	1	1	1	1	0	1
Industrial land	1	1	1	1	1	0	1
Public facil-ity	1	1	1	1	1	0	1
Railway	0	0	0	0	0	0	0
Green land	1	1	1	1	1	0	1

0 conversion impossible
1 conversion possible

Actually the setting of these two parameters is mainly based on the expert knowledge and historical behavior. This setting will be tested in the model sensitivity.

5.4.3. Reserved area

On the basis of the spatial policy in the case study area, there are some restricted areas referred in the section 4.5.4. With the prepared data, protected water body map, reserved agriculture land map, nature scene reserve map and preventing flood zone map were merged into one and reclassified into only two class categories: -9998 means restricted area with no changes in land use and 0 means active area without constrain (shown as figure 5-6).

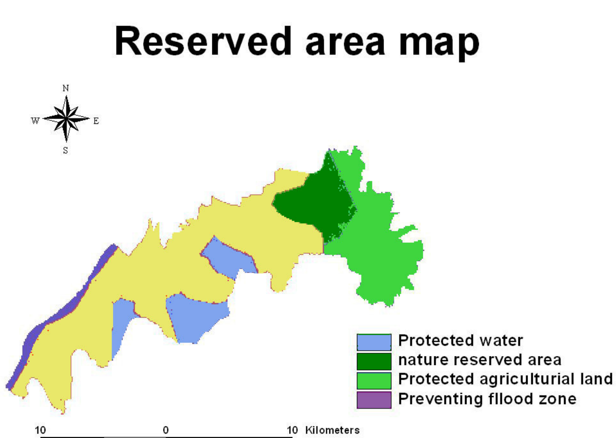


Figure 5.6 Reserved area map

5.4.4. Dynamic driving factors

Two types of files that specify the driving factors of land use change are distinguished. The first type of driving factors remains constant during the simulation period while the second type changes while the second type changes. In the case study area, the main dynamic factor is the main road. Because the third road ring of Wuhan will cross the Hongshan area around in 2006 according to Wuhan master plan (1996-2020). In the simulation period (1996-2010), the new main road network will emerge. This should be defined as a special file and in the next sections the effects of this factor will be seen in the simulation scenarios. The relative map can be derived from the transportation scheme of Wuhan master plan.

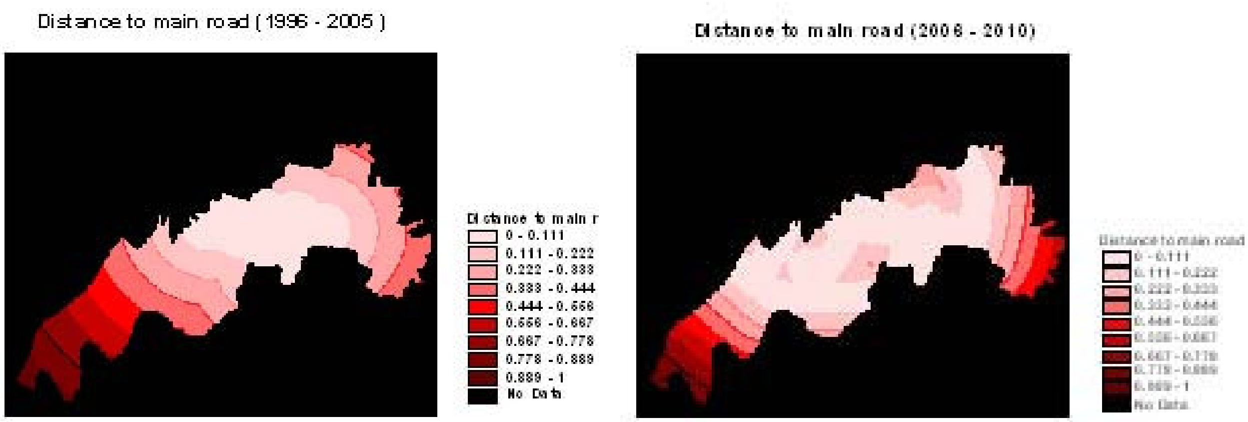


Figure 5.7 Dynamic factor

5.4.5. Visualization of the changed land use pattern

CLUE model calculates land use change year by year based on the demand scenario. So it is possible to understanding the dynamic development of the study area though these serialization maps. In each model step, the current spatial pattern of the study area is recorded as an ASCII file. These files can be imported by a GIS package (Arc View, Arc Gis and Idrisi) and explicitly presented.

5.5. Simulation scenarios and interpretations

Scenario is a statement of assumptions about the operating environment of a particular system at a given time. It is a reasonable pathway to explore the possible future. CLUE model not only tell us what and where is likely to occur leading from present situation (figure but also gives the insight of the different impacts on the basis of different alternatives. In the study area, water body and agriculture decrease seriously as a consequence of urban fringe's development. Therefore two alternative scenarios will be formulated: one is with the strict protection of the reserved area, and the other is without this restriction. This spatially explicit information would be especially important for the land use planners. They need to anticipate where conversions are most likely to occurring next focusing policy interventions.

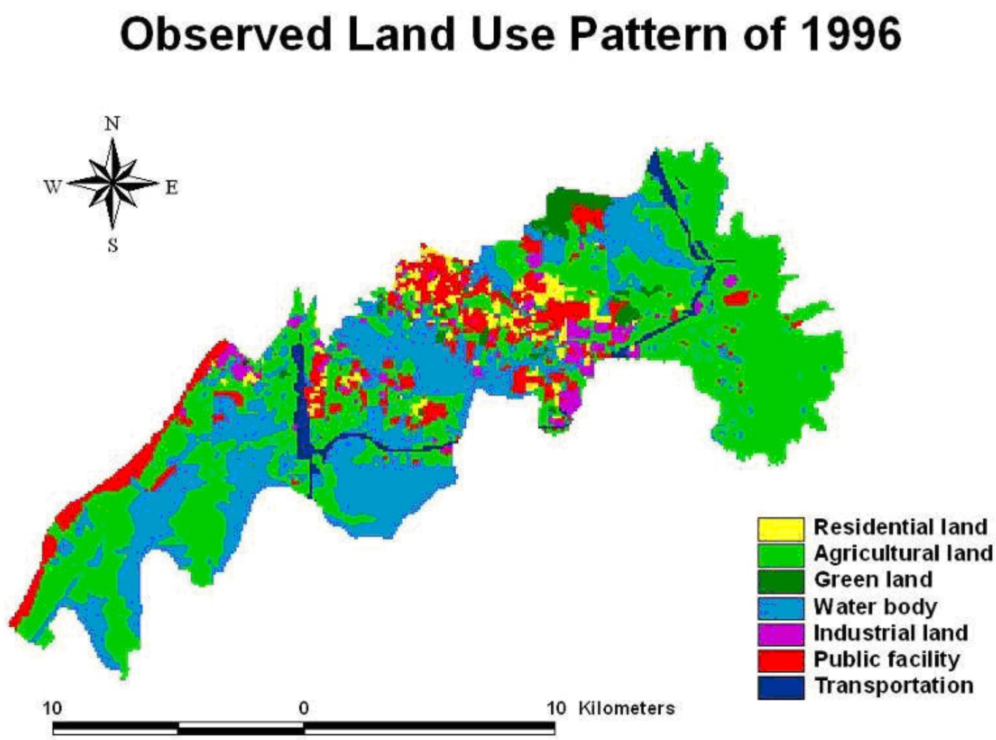


Figure 5.8 Observed land use pattern of 1996

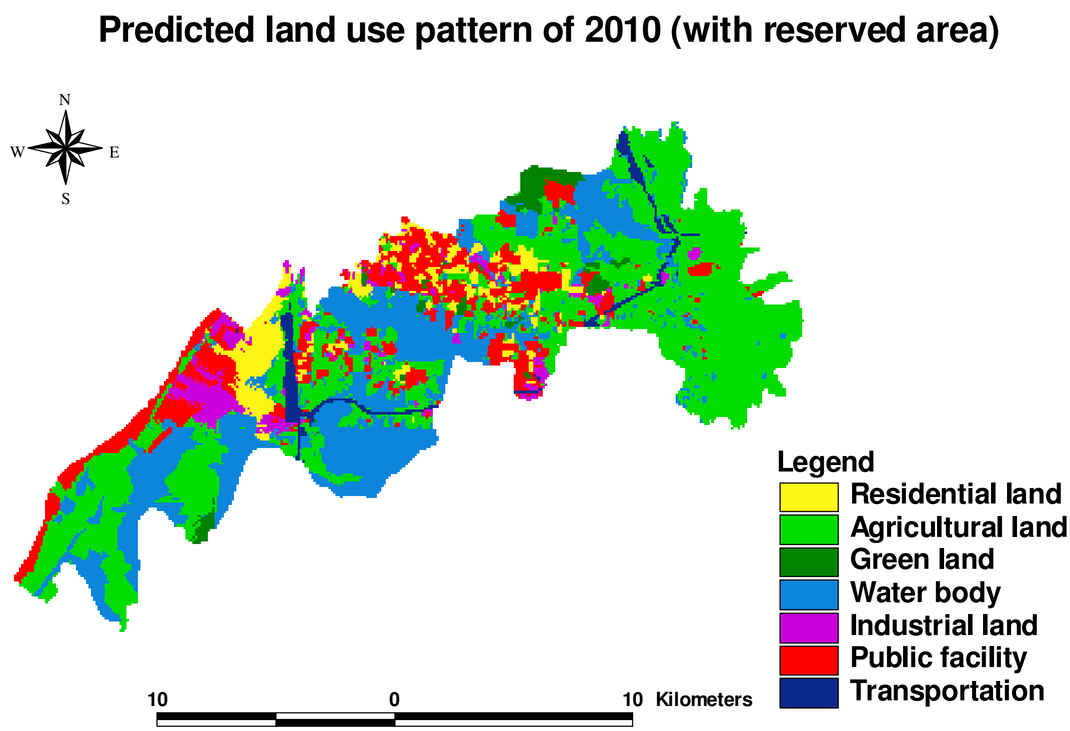


Figure 5.9 Predicted land use pattern of 2010 (with reserved area)

5.5.1. Scenario with reserved area

The scenario of the simulation result with reserved area in Hongshan area is presented graphically in figure 5-8 and 5-9. Figure 5-8 shows the spatial land use pattern in 1996, the referenced year. The land use pattern as simulated for 2010 is indicated in figure 5-9. The results suggest the 'hot spots' of land use change is found in the southern part of Hongshan District, especially around the future third road ring of Wuhan city.

These roads will direct the development of this fringe area.

Figure 5-10 presents the simulated results for the different land use types. Results for the transportation (railway) have been omitted because of the hypothesis for its stability.

Most increase in residential land is found in Shizishang street and Qingling Township, which are the foreland for the urban expansion. Green land grows slightly indicated by the result. A new green land is allocated near the Tangxun Lake for its good environment and accessibility. The pattern for the agricultural land and water seem similar. They are expected to face large decreases responsible for the urbanization in this area. This decrease mainly takes place in the Qingling Township near the main roads and the middle part of Hongshan Distrit. By contraries, public facility will occupy that place. For the industry land, it increases in the Qingling Township and decreases in the foregoing industry zone. It indicates that more industry will move out of the zone if the Industry Zone can not become an 'attractor'.

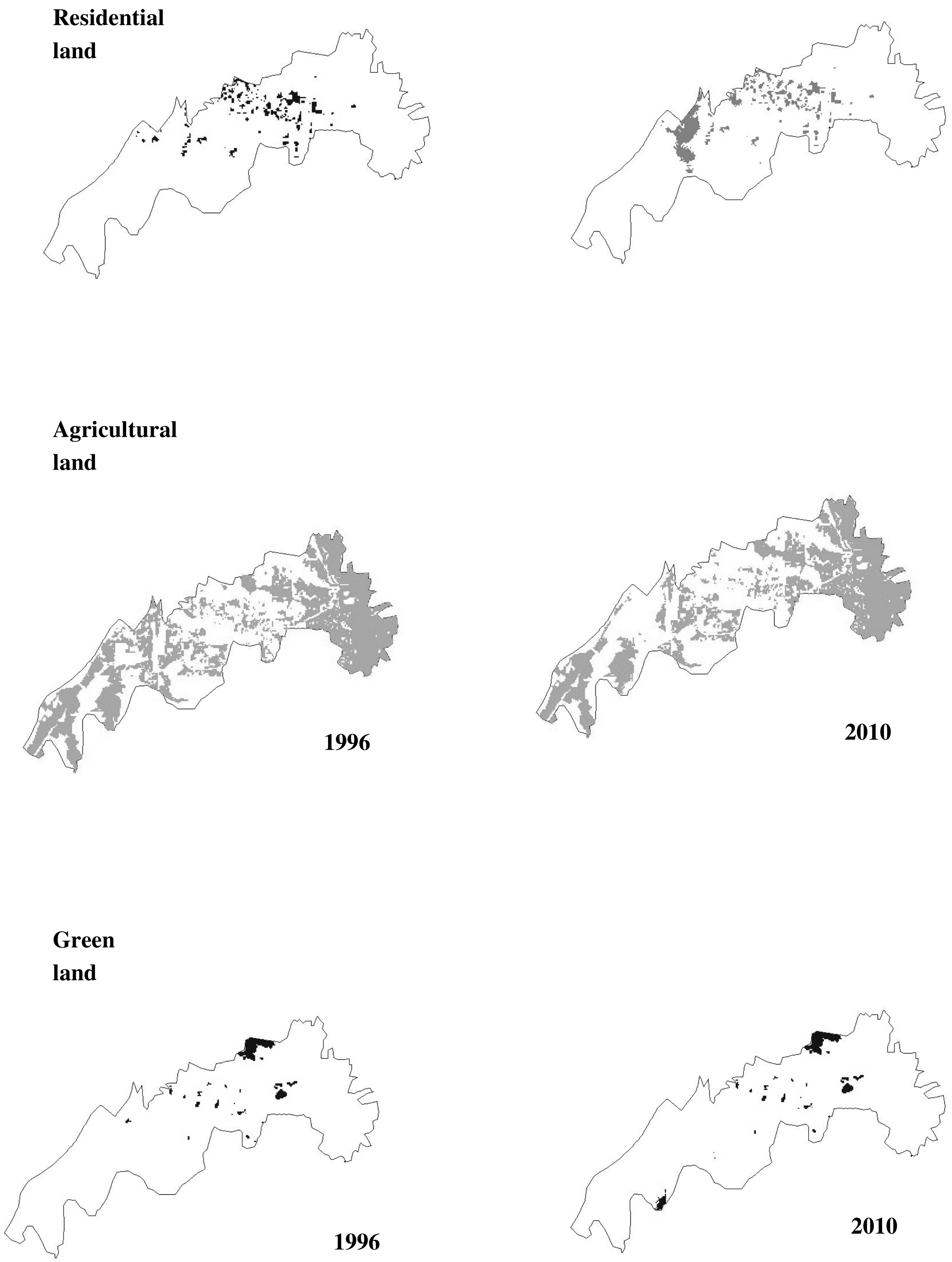
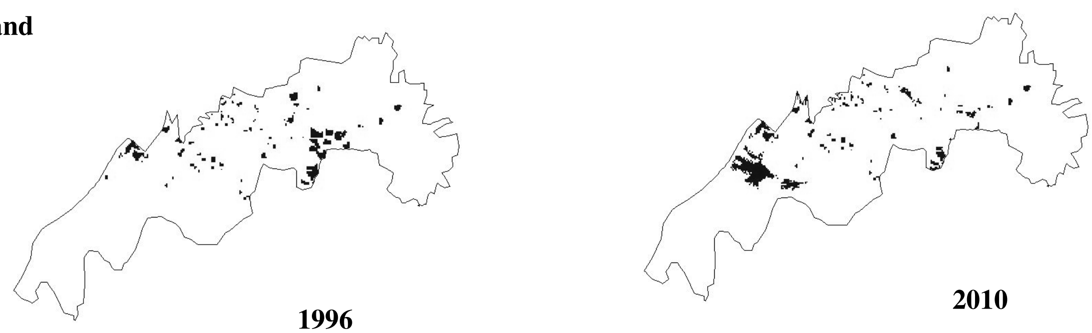


Figure 5.10 The spatial pattern of different land use types in 1996 and 2010(with restriction)

Water

Industrial land



Public facility

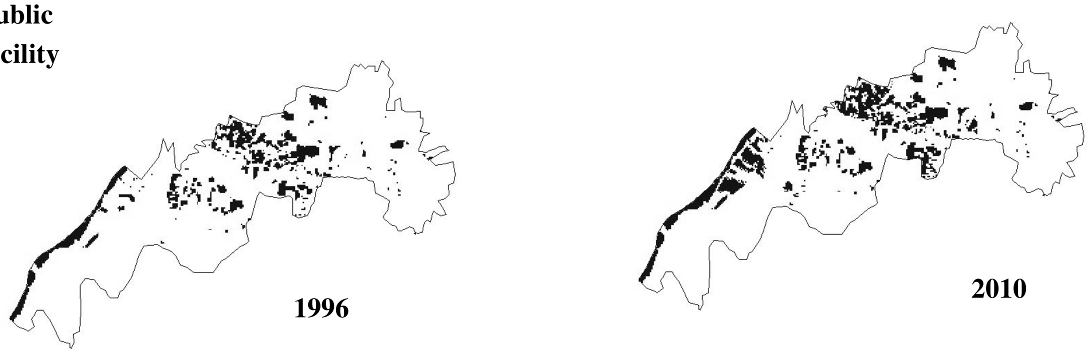


Figure 5-10 Continued

5.5.2. Scenario without restriction

Figure 5-11 answers the question that what is likely to occur if the strict protection for the reserved area is abolished. Figure 5-12 shows the simulation results for different land use type in 2010 for this alternative. The land use pattern of 1996 was not shown for this scenario because it can be referred to figure 5-11. Once there is no protection policy, it is found that residential land is expected to entry into the nature scene protected zone and industrial land is possible to occupy the fringe of Tangxun Lake. The agriculture protected area and the special zone for preventing flood are influenced lightly. Despite these areas, the simulated land use pattern is similar as the above scenario.

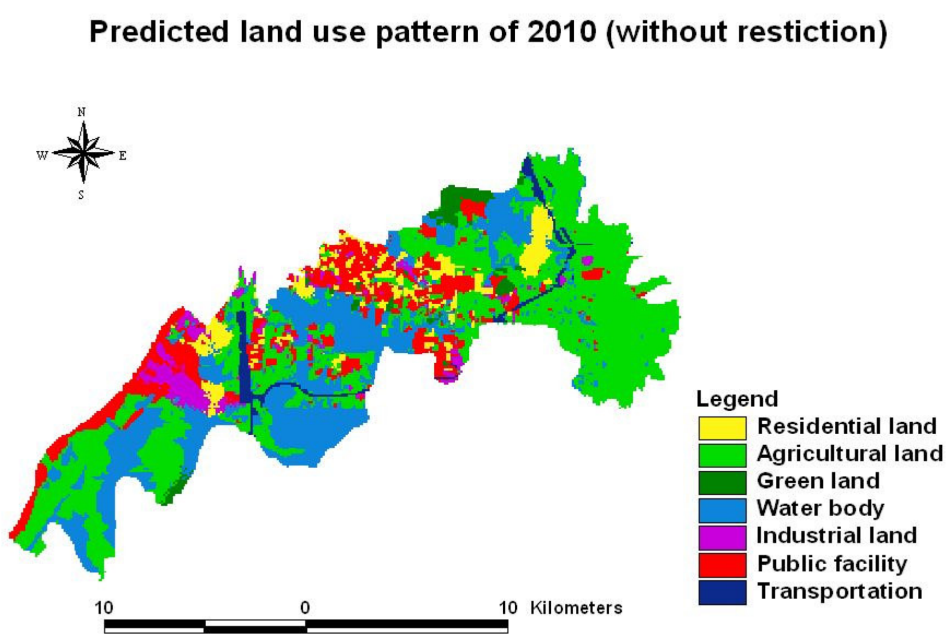


Figure 5.11 Predicted land use pattern of 2010 (without restriction)

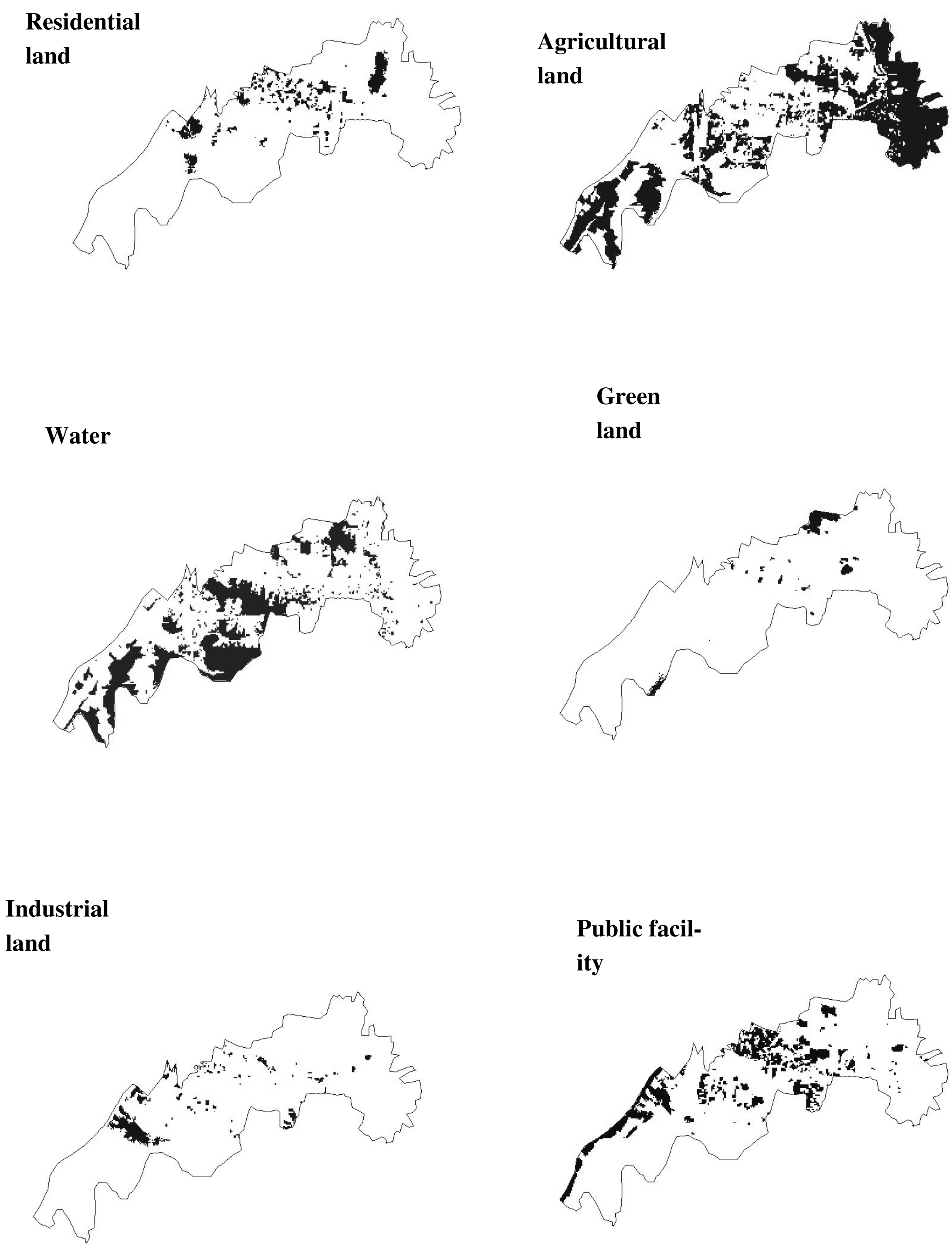


Figure 5.12 The spatial pattern of different land use types in 2010 (without restriction)

5.6. Model validation and evalution

5.6.1. Sensitivity analysis

The model is sensitive to the user specifies decision rules that steer the conversion based on the actual land-use pattern. The influence of the elasticity to change will be tested by setting the extreme parameter. A lower parameter number set should show a more dynamic behaviour of the spatial distribution. After that, the relative parameters were identified which can be referred in section 5.4.2.

5.6.2. Validation

High levels of uncertainty are common in the modelling of complex systems integrating human-environment interactions. A validation of the performance of the CLUE model has been made for a number of countries and resulted in confidence in the simulation of land-use change dynamics (Verburge P.H. and Veldkamp A. 2001). Unfortunately, validation in this study area is difficulty due to the poor data. Especially a number of residential lands are classified as public facility in 2002.By vision comparison (Figure 5-13 and figure 5-14), the model results are not very similar to the real land use pattern. There caution with interpretations of modelling results would still hold when an independent, comparable data set on land use are available for the validation of the model for Hongshan District.

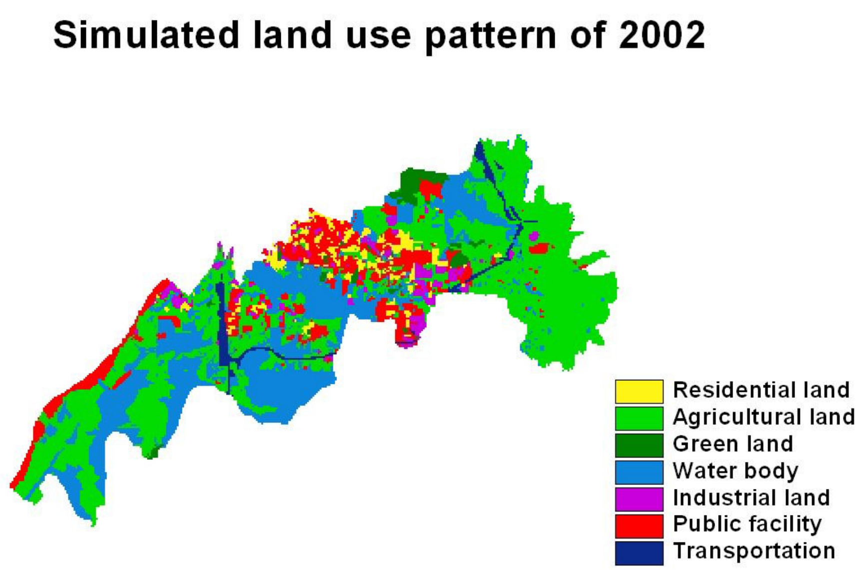


Figure 5.13 Simulate land use pattern of 2002

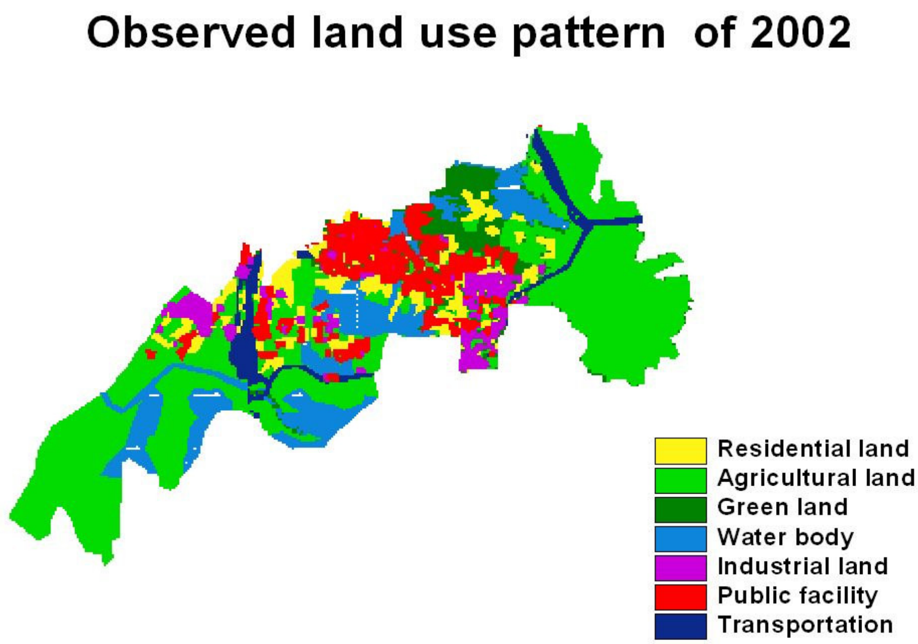


Figure 5.14 Observed land use pattern of 2002

5.7. Conclusions

The logistic regression of land use pattern provides us with insights into the significant factors determining the land use change in Hongshan District, a typical fringe area of Wuhan city. It also identifies the problems this area is facing with respect to the decreasing of agriculture land and water bodies. The spatially explicit results can be used to indicate various impacts in term of different alternatives.

6. Discussion & CONCLUSIONS

6.1. Discussion

In this research, efforts were focused on applying CLUE model to understanding the development of one urban fringe area. In the following section, some problems encountered in this research will be discussed and then the conclusion of this research will be given based on the findings of this research.

6.1.1. Reality and model

CLUE model is one kind of application of modelling and simulation methods. Modelling means to make prototype, design and representation something. Model is an idealized and structured representation of a part of reality. A model can serve as a good tool to mimic part of the complex and dynamic system. With the help of modelling, people can get to know some possible happen thing before it real happen on the basis of simulations derived from models. Urban planning is a future-oriented activity, strongly conditioned by the past and present. Thus modelling provides an important tool for planners to enhance their analytical, problem-solving and decision-making capabilities. It offers the possibility to test the sensitivity of land use (pattern) to changes in selected variable and the stability of the entire system by executing a range of scenarios. It provides valuable information on the system's behaviours under a range of different future pathways of land use change.

6.1.2. DPSIR model

A "process or behavior" model, DPSIR, was implemented to help identify the possible factors influencing the development of urban fringe. The DPSIR model helps to understand the cause and effect relationship between interacting components of a complex system. The land use system in the urban fringe is complex. A number of social, economic and environment factors contribute to the diverse land use types. DPSIR model is proved useful to describe the system and found out the possible factors underlying respective land use type. It connects the five junctures (driving forces, pressures, states, impacts and responses) with the DPSIR arrows, which indicate their interactive relationships. Therefore these inter-related factors are able to be present explicitly and rationally in a qualitative way. Compared with dynamic systems analysis methods such as Stella and VENSIM, DPSIR is a relatively simple but better method for reasoning the land use change.

In my study, DPSIR model comes across the whole process of CLUE modelling. CLUE model is based on the logistic regression, which examines the relative strength and significance of the all possible factors (explanatory variables). However only with regression analysis, the understanding about how the factors work in the whole system is weak. The multiple impacts caused by these factors could not be distinguished by the logistic regression. And more precise factors can be found out attributed to the explicit pressures and states. In addition, the different effects on the future land with different responses could be seen in the consequences of CLUE model.

From the different disciplines, the mixture of influential factors behind the land use types may be identified variously. In this research, all land use DPSIR models are based upon the general driving forces of urban fringe's development in Wuhan, which is summarized by literature and interview with local planners.

6.1.3. CLUE model

The framework of CLUE model

The model structure clearly represents the hierarchical organization of land use system, allowing for the 'top-down' and 'down-top' iteration between regional level demands and local level land suitability. In addition, the determinate factors can be taken into account. Coupled with GIS, its simulated results are spatially explicit. In this sense, the model has an appropriate structure to study the dynamic land use system.

On the basis of the framework for planning and decision-making, the methodology in this study fits well in the intelligence phase and the design phase. Chap2 and DPSIR model belongs to the intelligence phase of the research sequence. It describes the urban fringe, and assesses current situation of the case study area. Trends in land demand defined in demand module formulate the objective in that phase. In the design phase, CLUE model is developed for Hongshan District and spatially explicit results are obtained based on optimised land-use configurations (logistic regression). However, there is no subsequent handling to complete the framework of planning and decision-making. The impacts of alternatives are not evaluated. If the CLUE model is combined with Mulino, the output would be more useful for decision makes.

Furthermore, the linkage between the decision-making process by the individual actors of land-use change and the emerging patterns of land use is not well understood with the CLUE. These agents' behaviours would greatly influence the land use pattern, especially in China. If it is combined with multi-agent, the model may be possible to gain further understanding of the land use system.

Logistic regression

Logistic regression attempts to identify explicitly the causes of land use changes using possible factors. It is advantageous in its dependent variable, explanatory and normality assumption.

Care is needed with a direct comparison between land use types and single independent variables. It is the special combination of all these variables that create the conditions for land use system to express.

In this study only one year was investigated because of limitations in data availability. Time series can be a valuable extension of the current study. Wu and Yeh (1997) once applied logistic regression methods for modelling land development pattern in two periods (1979–1987 and 1987-1992). They found that the major determinants of land development have changed: from distance to the city center to closeness to the city center; from proximity to inter-city highway to proximity to city streets; and from more related to less related to the physical condition of the sites. It shows that various facts are changing their roles in the process of land development.

In the case study area which is located in the urban fringe, the change is more rapid. The model has been built upon the historic data of 1996. Actually in that period, some new factors are emerging, such as the construction of a state-level Agriculture Zone and expansion of universities. These new-involved factors may be influencing the land use change but not included into the regression result. Further improvements are expected to do the regression result of 2002 with the availability of large data sets.

Data adequacy

For the modelling method, data is always parsimony. The logistic regression is based on a mass of historic data. But the management of historical data is poor in Wuhan city, especially in Hongshan as a fringe area. It is difficult to get the high-resolution land use map and social-economic information even for current situation. More detailed data especially socio-economic data in the case study area will improve the simulation accuracy. This study can only use as much the as we can get. To take this prospect into account, the CLUE-HS model will get a better result if more data are available.

6.2. Future work

Through the six months' work, CLUE model is successfully developed to help understand the development of Hongshan District in my option. But further explorations may contribute to enrichment of the research on urban fringe and urban modelling.

6.2.1. Neighbourhood function

Neighbourhood interactions between land use types are often included in the spatially explicit analysis of land use change. Especially in the context of land use change, neighbourhood interactions are often addressed based on the notion that urban development can be conceived as a self-organizing system. Spatial interaction between the locations of facilities, residential land and industry land should be given more attention in future research. In the urban fringe of China, new residential land may arises for the neighbourhood interaction from industrial land. The neighbourhood function has recently been embedded into CLUE model, so it is possible to do more dynamic simulation work.

6.2.2. To simulate two urban fringes and compare their coefficients and scenarios

In this study, efforts are focused on one urban fringe. The results indicate the land use pattern of Hongshan District, but it still cannot contribute to understand the general development of urban fringe in Wuhan. Comparative studies are useful for better understanding difference and similarities. So the future work will be associated with the spatial pattern of two or more urban fringe areas.

6.3. Conclusions

The main objective for this research is to gain understanding of factors explaining the development of one urban fringe area in Wuhan and simulate the trend of the case study area's development.

- To identify the possible factors affecting land use change in urban fringe
- To find out the essential factors through logistic regression model
- To develop the CLUE model for the case study area
- To present the future land use patterns with different alternatives

In this research, the development of urban fringe is understood and a spatially explicit model, CLUE model has been developed for simulating the land use pattern of Hongshan District, the fringe of Wuhan city, China.

Possible factors underlying every kind of land use type were identified with the help of DPSIR model. And the significant factors influencing the land use change in Hongshan District were found out through the logistic regression model. The regression results can be evaluated by the ROC method. It is confirmed that proximity to the main road is an important factor for the development of urban fringe.

After the demand for every land use allocation and restricted area were defined, the possible future land use patterns were simulated by CLUE model. And the results were exported by GIS package for visualization of the land use change.

Thus, conclusions can be addressed as:

- CLUE is a useful tool to model land use pattern of the urban fringe in Hongshan
- DPSIR model is a simple and good tool to identify the possible factor of the land use change
- Main road is found out as the determinative factor for the land use change in Hongshan through logistic regression.
- Different spatial policies will have different impacts on the land use pattern

In summary, most of the objectives have been achieved through this research.

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Appendices

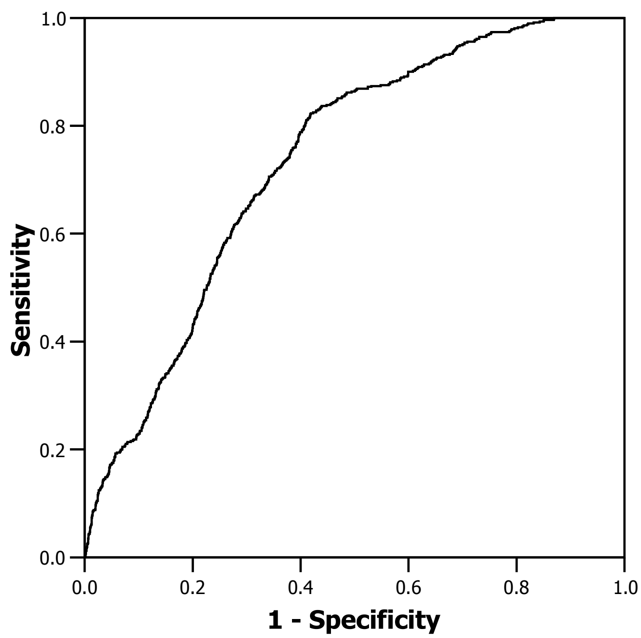
Appendix1: Logistic regression result

Residential land

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 6(f)	V1	-.717	.126	32.489	1	.000	.488
	V4	-8.711	1.162	56.176	1	.000	.000
	V7	2.756	.419	43.309	1	.000	15.740
	V8	-8.887	1.100	65.303	1	.000	.000
	V11	5.793	1.141	25.763	1	.000	328.134
	V14	6.333	.822	59.354	1	.000	562.951
	Con-stant	-3.095	.158	381.757	1	.000	.045

ROC Curve



Diagonal segments are produced by ties.

Area Under the Curve

Test Result Variable(s): Predicted probability

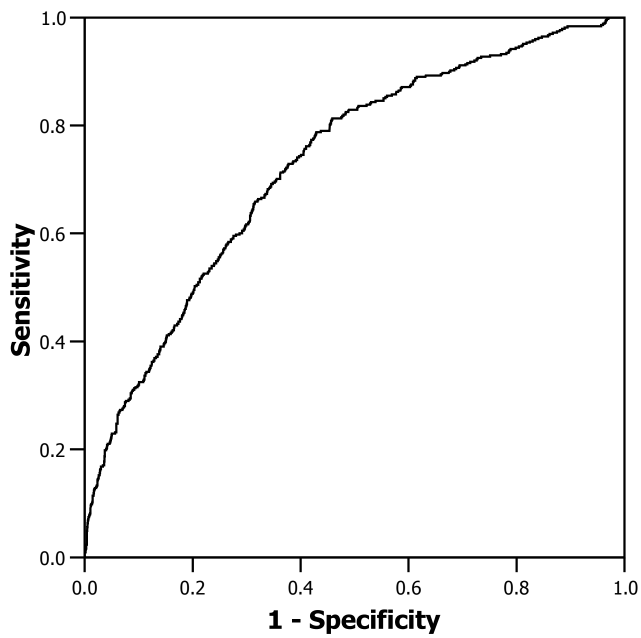
Area
.734

Green land

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 6(e)	V1	-1.040	.186	31.146	1	.000	.354
	V3	-5.755	.445	166.865	1	.000	.003
	V4	-10.024	.841	142.223	1	.000	.000
	V8	14.739	1.171	158.499	1	.000	2518663.301
	Constant	-3.343	.120	774.164	1	.000	.035

ROC Curve



Diagonal segments are produced by ties.

Area Under the Curve

Test Result Variable(s): Predicted probability

Area
.728

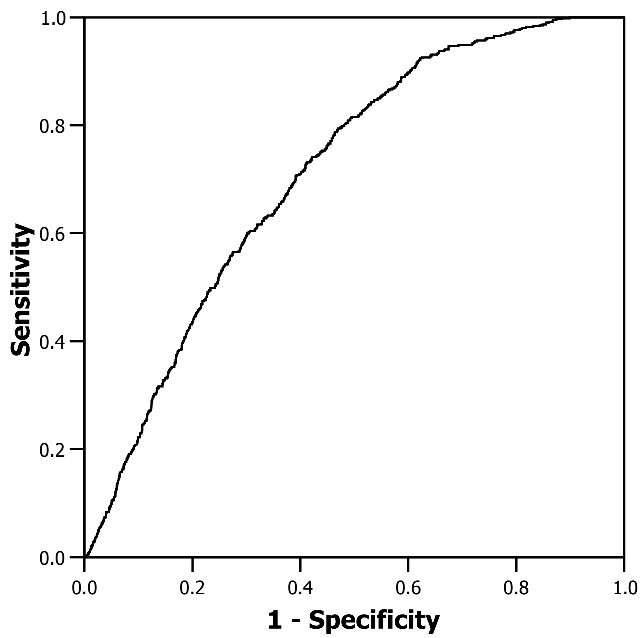
The test result variable(s): Predicted probability has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

Industrial land

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 6(f)	V4	-20.771	1.469	199.972	1	.000	.000
	V5	8.731	1.924	20.589	1	.000	6192.379
	V6	2.123	.548	14.994	1	.000	8.357
	V9	-1.365	.345	15.694	1	.000	.255
	V11	12.095	1.420	72.529	1	.000	179021.758
	V13	-6.915	2.224	9.668	1	.002	.001
	Constant	-2.512	.205	149.531	1	.000	.081

ROC Curve



Diagonal segments are produced by ties.

Area Under the Curve

Test Result Variable(s): Predicted probability

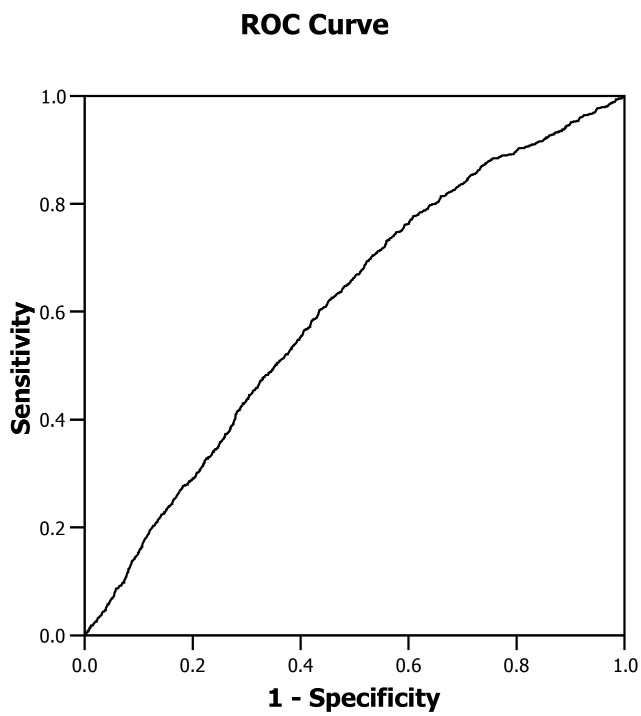
Area
.710

The test result variable(s): Predicted probability has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.

Public facility

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 3(c)	V4	-5.697	.516	121.665	1	.000	.003
	V10	1.016	.186	29.906	1	.000	2.762
	V11	4.185	.510	67.340	1	.000	65.701
	Constant	-2.390	.112	455.682	1	.000	.092



Diagonal segments are produced by ties.

Area Under the Curve

Test Result Variable(s): Predicted probability

Area
.606

The test result variable(s): Predicted probability has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.