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Name: Xintong Li

Supervisor: Oliver Lah

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Institute for Housing and Urban Development Studies of Erasmus University Rotterdam

Summary

Ecosystem services refer to the conditions and benefits that ecosystems can provide to humans and during the process of maintaining their own material cycle and energy conversion (Postel, Bawa, et al., 2012). An ecosystem can provide services to human society and economic development in different forms so that human living environment can be purified, climate conditions can be regulated, and development needs can be met (Postel, Bawa, et al., 2012). At the same time, the ecosystem system can support the development of biological diversity through its own carrying capacity and provide more types of ecological services to human beings, bringing great utilization value to human beings. Therefore, the economic construction of cities mostly depends on the urban ecosystem system (Peng, 2016). However, due to the rapid development of cities, the expansion of population, the rapid change of land use and other problems, the phenomenon of excessive waste of resources and rapid deterioration of ecological environment has resulted in an obvious decline in the value of urban ecosystem services (Yang, Chang, et al., 2008). Therefore, analyzing the value of ecosystem services from a quantitative perspective and defining the relationship between human activities and natural ecological system is conducive to ensuring the sustainable society and the benign development of the urban ecosystem.

The main purpose of this thesis is to study how changes in land use types can have an influence on urban ecosystem services value. In order to study this issue, three sub-questions were raised.

(1) What changes happened to the land use types of Wuhan during 2008-2018?
(2) To what extent has Wuhan's UESV changed during 2008-2018?
(3) How does the change of LUCC in Wuhan explain the change of UESV in Wuhan during 2008-2018?

This thesis selects Wuhan, a fast-growing economy in China, as a research area. Wuhan is a long-established city in China. After thousands of years of development, it has made great progress. In the past development process, the dependence on land is the root cause of human beings changing the appearance of natural ecosystems (He, Li, et al., 2015). Located in the central part of China, Wuhan is dominated by plains with a small number of low hills (Wuhan Government, 2018). Based on the remote sensing interpretation data of 2008, 2013 and 2018, quantitatively analyses the changes of land use in Wuhan and the changes in ecosystem value caused by it, and discusses its value and the relationship between the structure of land use types, In the end, provides a reference for decision-making on the sustainable use of regional land resources and the construction of ecological environment. The results show that the relevant degree of the surface water body and cultivated land to urban ecosystem services is higher than other land use types, ranking the first and second, followed by forest land and built-up area.

Keywords

Urban ecosystem services, Urban ecosystem services value, Land use and land cover change, Evaluation of UESV, Evaluation of LUCC, Wuhan

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Foreword

The ecosystem on Earth is a complex life support system. Human sustainable development must protect this life support system and maintain the sustainability of ecosystem services (Kreuter, Harris, et al., 2001). Ecosystem services refer to life support products and services that are directly or indirectly obtained through the structure, processes and functions of ecosystems which can be divided into two parts: the products necessary for human life and the ecological functions that guarantee the quality of human life (Costanza, d'Arge, et al., 1997). However, how to accurately and effectively evaluate ESV is still a hot issue for ecologists and economists. As one of the core areas of global environmental change research, Land Use and Land Cover Change, LUCC plays a decisive role in maintaining the service function of ecosystems by changing the structure and function of ecosystems (Turner, Skole, et al., 1995).

In recent years, Wuhan's economy has developed rapidly, including various natural factors as well as human and biological activities, and its ecosystem is complexity and particularity. When the level of urbanization continues to increase, a large number of land use types and urban landscapes (Longmei, Xuelei, et al., 2005) change, but due to the poor stability of the ecosystem in Wuhan and the fragile ecological environment, it is unable to withstand excessive development activities. Based on the study of Wuhan's rapid urbanization, this thesis reflects the impact of land use type changes on UESV by evaluating the UESV changes caused by LUCC and provides decision-making support for the sustainable use of land resources and ecological environment protection in Wuhan.

Abbreviations

IHS	Institute for Housing and Urban Development
UES	Urban Ecosystem Services
LUCC	Land Use and Land Cover Change
UESV	Urban Ecosystem Services Value
VC	Value Coefficient
CS	Coefficient of Sensitivity
DPS	Data Processing System
GHG	Green House Gas
CPC	Communist Party of China
GIS	Geographic Information System
SLM	Sustainable Land Management
IGBP	The International Geosphere-Biosphere Programme
IHDP	The International Human Dimension Programme on Global Environmental Change
MEA	The Millennium Ecosystem Assessment
CVM	Contingent Valuation Method

Table of Contents

List of Boxes

List of Charts

List of Figures

List of Tables

Chapter 1: Introduction

1.1 Background

China has experienced rapid urbanization in the past 30 years. China has experienced rapid urbanization in the past 30 years. China's urbanization is the largest in the history of urbanization in the world, with the most complex background, the most beneficiary population, and the most prominent urbanization (Peihong and Jiuwen, 2011). According to the data of the sixth census (National Bureau of Statistics of China, 2011): In 2011, China's urban population was 660 million, accounting for 49.68% of the total population. The resident urban population and rural population are very close. The "13th Five-Year Plan" (Outline of the Thirteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China, 2015) proposes that at the end of the period, China's urbanization rate will reach 54%. By then, the urban population will exceed the number of rural populations, and China will enter the ranks of urban-type countries. When the urban population accounts for more than 50% of the total population, the status of cities in the development of the country will continue to rise, not only being the central area of economy, society and culture, but also becoming the leading force of economic, social and cultural development (Peihong and Jiuwen, 2011). It is predicted that by 2050, 75.8% of Chinese will live in urban, and the total population of the urban will exceed 900 million (United Nations, 2015). The demand for built-up area and resources in urban centres and surrounding areas will increase, and the demand for good quality of life and healthy urban environments will also increase. In the construction of China's development has never get rid of the characteristics of "high investment, high energy consumption, high pollution and low efficiency", which has made the ecological environment pay a huge price(Zhang, 2008). At the same time, during the process of city construction and development, the ecological environment is facing a very severe circumstance. The environmental pollution and ecological damage brought by the extensive resources using have become the bottleneck restricting economic development. How to mitigate and reduce the negative impacts of urbanization, and thus improve urban sustainability, is an important challenge for urban development.

"New Urban Agenda" put forward that through the well"Building the urban governance structure: establishing a supportive framework" and excellent "Planning and managing urban spatial development" will make the most of the positive role of urbanization to address global challenges such as climate change and social differentiation (New Urban Agenda, 2016). It advocates a new urban paradigm of social inclusion, good planning, environmental sustainability and economic prosperity, which poses new challenges to the global urban and regional planning.

According to Wu (Wu, 2014): "urban sustainability refers to the ability of urban to maintain and improve ecosystem services and human well-being". Urban ecosystem services are the basic material conditions for maintaining and improving human well-being, and also an important channel for promoting sustainable urban development. Therefore, urban ecosystem services (UES) is the basic condition for human survival and development and is the key natural capital which provides important inputs to change environment and well-being (Fisher and Turner, 2008). The increasing global environmental problems have made UES value evaluation more and more concerned. The quantitative assessment of UES value has become one of the hot spots of international sustainable development and ecological research.

As a purposeful and conscious activity of human beings, Land use and land cover change (LUCC) runs through the whole historical process of human society which has a significant impact on the ecological environment (Pielke RA, 2005).

1.2 Problem statement

Globally, the key issues that threaten UES and land-use system are: "(a) soil degradation, (b) water scarcity and pollution, and (c) loss of biodiversity" (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, 1996). These problems occur in LUCC management systems in almost all socio-economic environments around the world. On the other hand, there is significant differentiation in the capacity of countries to address these critical issues (Hurni, 2000). The pressure is particularly high in China, due to the previous economic development mode of sacrificing urban ecosystem environment to develop, China's economic growth model is transforming from "extensive"(also called unreasonable development) to "sustainable development". and land use type is also in a dramatic change stage. During this period, many "historical issues" need to be resolved, such as heavy population burden, shortage of resources and fragile ecological environment (Kun, 2014).

In the past urbanization development of China, less attention was paid to UES, resulting in lack of land area of green infrastructure such as green space and wetland, which directly affected the function of urban ecosystem services. Resource and ecological issues are exacerbating, especially the economic beneficiaries and environmental governance in urban development, between suppliers and consumers in UES. Changes in LUCC types are strongly associated with human activities, and it is also one of the important reasons that affect the value of UES (Zhang, Zhao, et al., 2015). Changes in land use types can directly cause alterations in the spatial pattern of the ecosystem, and also have a huge impact on the structure, development process and service role of the ecological environment which will ultimately affect the UES (Zhang, Zhao, et al., 2015).

In the context of China's urbanization, more and more urbanization problems have been exposed. People gradually realized that taking full advantage of UES is an operative way to work out the problem of urbanization. Evaluating the economic value of UES functionality not only allows people to visually recognize the importance of UES to cities and residents but also provides more reference information for urban planning and decision makers. Neglecting the value of this objective existence will inevitably underestimate the importance of UES, and the urban planning based on this will also be distorted, leading to decision-making mistakes.

The contradiction between China's urbanization development and UES begins to intensify, and the "urban disease" has affected the sustainable development of some megacities (Guilong and Wei, 2013). According to the bluebook "Beijing, Tianjin and Hebei development report (2013) -- carrying capacity measurement and countermeasures", the adverse consequences brought by water resource depletion, garbage-surrounded city, haze, traffic congestion and overpopulation in Beijing, Tianjin and Hebei region are gradually emerging. This is the "contradiction" mentioned earlier. For the development of the city, the water source in and around the city is used without regard to the consequences. Urban waste is directly buried in suburban areas without effective classification, leading to "garbage-surrounded city" which is only to save disposal costs. In the winter, un- sulfurization coal is used for heating, in order to save processing costs resulting in rampant smog. Living standards of residents have been improved under the background of rapid urban development, leading to a sharp increase in the number of vehicles per capita, which leads to urban traffic congestion, and excessive automobile exhaust emissions aggravate the haze, forming a vicious circle. Of the six outstanding issues that must be addressed in the "National New Type Urbanization Planning (2014-2020)" (The CPC Central Committee, The State Council, 2014), four are closely related to environmental resources, which fully reflects that ecological environment and resource issues are major weaknesses and constraints of China's urbanization development.

China's rapid economic development has caused different degrees of impact on UES:

unreasonable development (also called extensive development pattern mentioned above), utilization and waste of resources destroy urban ecology and pollute the environment. On the other hand, with the economic development, technological progress, raising the level of pollution prevention and implementation of various regulations and policy improved UES condition. Especially, with carried out the comprehensive improvement of the urban, small watershed comprehensive treatment, the total local pollutant amount has been controlled and a series of measures such as discharge permit system published to control the trend of ecological environment deterioration in China.

Haines-Young and Potschin said (2010): “Services do not exist in isolation from people’s needs”. Residents and ecosystems in cities are two important components of the city, and the two influence each other. At the same time, both of them experience constantly variation with the development of urbanization process. UES comprehensively reflect the supporting function of ecosystems to urban development. It is the unity of supply and demand. The relationship between the LUCC demand for urban development and the limited supply of UES is a process of dynamic equilibrium (Yang, Hu, et al., 2007).

1.3 Research objectives

Costanza, etc., published “The value of the world's ecosystem services and natural capital” in Nature, which made the principle and method of estimating the value of UES clear in the scientific sense (Costanza, d'Arge, et al., 1997). Accurate estimates can make people pay attention to the balance between urban development and the urban ecosystem environment (Gómez-Baggethun and Barton, 2013). Chapter 3 will describe how Costanza's UES value estimation principle is used in the conceptual framework. In this thesis combining the value assessment of UES with LUCC helps decision makers fully understand the complexity of UES and further keep the balances of the developing relationship between the two when making decisions.

The thesis will adopt the methodology of Costanza et al. and will collect changes in the type of land use in Wuhan from 1995 to 2015 to use existing models and formulas with GIS to analyse the changes of land use types and calculate changes in UES caused by changes in LUCC types, and analyse the association and sensitivity within the two. The research will sequence the transformation of land use types with different levels of influence and conclude which types of land types increase or decrease the impact on the value of UES. This thesis aims to find a way to rationally rank the sequence of urban land use types change through the study of the degree of influence of UES, to provide a reference for scientific decision-making by the local government to formulate urban ecosystem protection policies, develop urban eco-tourism, improve residents' well-being, and promote sustainable urban development.

Box 1: Research objective

The main objective of the research is to find a way to rationally rank the sequence of urban land use types change through the study of the degree of influence of UES, to provide a reference for scientific decision-making by the local government to formulate urban ecosystem protection policies, develop urban eco-tourism, improve residents' well-being, and promote sustainable urban development.

Therefore, the specific objectives are:

- **Sequence the changes of land use types with different levels of influence.**
- **Conclude which kind of land use types increase or decrease the impact on UESV.**

1.4 Provisional research question

Box 2: Provisional research question

Overall research question:

"Which type of land use change can increase the value of urban ecosystem services in Wuhan？"

1.5 Significance of the study

With the continuous growth of the Earth's population, the impact of human beings on the UES is increasing, and the damage to the UES is becoming more seriously (Bloom, Canning, et al., 2008). Awareness of the importance of UES's values from the past existed only in the academic, gradually spread to the public, and initiated to affect the decision-making of urban development to some extent. In addition, changes in UES have in turn affected the of the urban economic development and human production and life. At present, the research on the value of UES has received worldwide attention. In general, studying the impact of changes in land use types on the value of UES has several implications:

It is propitious to improve the scientific nature of sustainable land management (SLM) and improve sustainable land use evaluation methodology. Most Lands-use management systems in the world are characterized by a lack of sustainability (Hurni, 2000). UES and urban land are likely to be used and managed in a sustainable manner if land management technologies are used appropriately to complement the policy frameworks for rational planning and decision makers within urban areas. The ideal final result is that SLM, which promotes the sustainable development of UES and enhances its value, is a management system that can benefit both urban development and the well-being of residents.

It helps to promote the transformation of the values of ecological and environmental assets and the popularization of the public and raising public awareness of environmental protection. The results of the research present the changes of UES caused by land use types in a form of monetization, making people aware of the changes in urban land use that do affect the UES, thereby improving people's awareness of UES protection.

Evaluating the value of UES can provide more valid information to city planners. For example, the loss of various UES and its direct or indirect economic losses should be fully considered. It is important to make full use of the government's investment in urban green infrastructure and scientifically evaluate the priority location of building new communities (Ring, Hansjürgens, et al., 2010).

1.6 Scope and limitations

Time scope: 2008-2018. Compared with China's long process of urbanization development, this thesis only selects a decade of Wuhan's relatively rapid economic development, which may be limited from a long-term perspective, because many policies were implemented during this period, but it takes longer for the results to show.

Space scope: 13 administrative region, 8494.41 square kilometres.

Calculation model: Due to the limitation of time and self-research ability, when calculating the land use type, it will be limited to a certain calculation model, and it is impossible to fully and comprehensively calculate the change of land use type.

Value coefficient: The value assessment of UES includes only a part of the indicators and does not include all UES indicators. And value coefficient is based on Costanza's study (Costanza, d'Arge, et al., 1997), Gaodi Xie (2003) combined the coefficient with China's conditions in his study. And then, Ruijuan Duan (2005) transformed it into one that could be used in cities. Although the coefficient used in this thesis is a commonly used one and has been published and verified for a long period, it is not calculated in this thesis and cannot be guaranteed.

In addition, in the evaluation of cultural services, it could be more accurate to use people's willingness to pay, because the method of monetization calculation is more intuitive, so the indicators use economic value to evaluate cultural services.

Chapter 2: Theory Review

This chapter reviews and discusses the concepts and research progress in two related concepts ("Land Use and Land Cover Change" and "Urban Ecosystem Services"). The land-related part introduced the origin of the LUCC concept, the current main research directions and evaluation models. The Chinese land classification system used in this paper was also introduced. In UES section, concepts, classifications, functions, and evaluation models are introduced. Finally, the research progress on the relationship between LUCC and UES is presented.

2.1 State of the Art of the Theories

2.1.1 Land use and land cover change (LUCC)

A research plan was formally presented in 1995 by "the International Geosphere-Biosphere Programme" (IGBP) and "the International Human Dimension Programme on Global Environmental Change" (IHDP) (Turner, Skole, et al., 1995). According to Turner, Skole, et al (1995): "Land use refers to the process and activities that human beings use to develop and utilize land to achieve social and economic goals by certain technologies and means. Land cover is officially defined by IGBP and IHDP as the natural state of the near-surface surface under the combined effect of natural and social factors." Land use change (LUC) under the influence of human activities will lead to changes in the structure and function of UES, which will have an impact on the ecological environment (Turner, Skole, et al., 1995). LUCC is an important manifestation of material and energy interaction between humans and the global environment, occurring at any time and space scale (Turner, Lambin, et al., , 2007). It not only influences the geographical spreading pattern and productivity of the ecosystem, but also objectively exhibits the change of the earth's biochemical cycle, the structure and function of the ecosystem, the supply of products and services, and also the process of temporal and spatial changes on the land surface (Foley, Defries, et al., 2005).

At present, the contents of LUCC research mainly include the following five aspects: LUCC status study, LUCC driving force analysis, LUCC environmental effects, LUCC model research (explained in 2.1.2 below) and LUCC data research.

(a) LUCC status study:

The status study describes, evaluates, interprets and predicts the quantity, quality, spatial distribution, classification, rate of change and process of LUCC (Dewan and Yamaguchi, 2009, Song, 2005). With the advancement of technology and the constant innovation of research methods, it may in turn cause researchers to re-examine and correct the original classification method. In the future, the scale-scale synergy, the accurate assessment of quality, the description of a dynamic process, and the unification of classification criteria are the focus of LUCC status research (Zheng, Lu, et al., 2017).

(b) LUCC driving force analysis

Driving force analysis is one of the more mature researches, especially in natural driving factors, including hydrology, topography, climate and other factors (Jobbágy and Jackson, 2000, Rost, Gerten, et al., 2008, Geist and Lambin, 2002). Economic and social research is also becoming more mature, according to IGBP and IHDP research reports (Turner, Skole, et al., 1995): "The socio-economic driving force can be divided into direct factors and indirect factors, among which indirect factors mainly include population change, wealth, technology development, political economy, political structure, concept and value. They pass the demand of land products and land.” LUCC is changed by direct factors such as input, degree of intensification of use, tenure, policy, and attitudes toward land resource protection (Turner, Skole, et al., 1995).

(c) LUCC data research

Data selection is based primarily on historical data such as policy changes, climate anomalies, and some satellite remote sensing images (Pian, Jiang, et al., 2015). Most of the information and data sources of LUCC research in the world are derived from the interpretation of various remote sensing satellite data and remote sensing images. However, in the process of interpreting remote sensing images, the researchers' image interpretation ability, the mastery of geoscience knowledge and the error of the image itself, the simple use of remote sensing data cannot accurately reflect the change process and trend of LUCC on the space-time scale. Therefore, LUCC research mostly uses multi-data sources such as remote sensing data and field survey data and statistical data to analyze the combination of field survey and indoor interpretation in the process of image processing (Pian, Jiang, et al., 2015). Data can be divided into historical source data and contemporary monitoring statistics by time. Historical statistics provide the possibility of historical land use and land cover change research, while contemporary remote sensing data has many advantages such as immediacy, large area, continuity, high resolution and so on (Zheng, Lu, et al., 2017).

2.1.2 Land Use Type Classification in China

Based on “National Standards for Classification of Land Use Status” (Baiming and Xiaoping, 2007), according to the two-level classification system of remote sensing interpretation of Chinese academy of sciences, the land use types in China are divided into level-one (six types) : **Cultivated land, Forest Land, Grass Land, Surface Water Body, Built-up Area and Vacant Land.**

Cultivated land: According to the topographical features, it is further divided into plains, hills, mountains and cultivated land with a slope of more than 25 degrees.

Forest Land: Refers to growing trees, shrubs, bamboos, forestry land such as coastal mangroves.

Grass Land: It refers to all kinds of grassland with growing herbaceous plants and coverage of more than 5%, including shrub grassland dominated by animal husbandry and sparse forest grassland with less than 10% canopy closure.

Surface Water Body: Refers to natural land waters and land for water conservancy facilities

Built-up Area: Refers to land for industrial and mining and transportation outside urban and rural settlements.

Vacant Land: Land not yet utilized, including hard-to-use land.

2.1.3 Evaluation of LUCC

With the increasing trend of LUCC model integration, the characteristics of spatial scale, analysis level and time dynamic are gradually blurred. The single model analyses both the situation of a certain scale and the dynamics of cross-scale; considering the specific time point Static features, including the evolution of the system over time (Verburg, Soepboer, et al., 2002). Although the empirical model and model concepts, processes based on a comprehensive study, in some cases, but most of the case studies in the use of two types of models are independent, the comprehensive level is relatively low. From the two major scientific research methods of epistemology (inductive method and deductive method) and their relationship of opposites, this paper divides the LUCC model into two categories: experience-statistical model and conceptual mechanism model.

(a) Empirical-statistical model

The empirical-statistical model uses multivariate analysis of the drivers that may affect LUCC or uses expert knowledge to clearly identify the cause of the change and quantify the interaction between LUCC and the driving factors to obtain a statistical rate of change (Lambin, Rounsevell, et al., 2000). The construction of such models often uses multivariate analysis methods, with multiple regression methods being the most common. According to the analysis target and data structure, empirical-statistical analysis methods can be divided into 4 categories (Lesschen, Verburg, et al., 2005): Exploratory data analysis, Regression, Bayesian and Training.

Although in many cases the application of empirical-statistical model helps to understand the drivers of LUCC, this technique has many drawbacks and limitations. First of all, the explanatory power of the model is not strong (Lambin, Rounsevell, et al., 2000). Although it is statistically significant in the various relationships identified by the model and have a strong ability to interpret changes, they do not confirm the causal relationship between the two. Second, the versatility of the model is poor (De Koning, Veldkamp, et al., 1998). At a certain scale within a region, the model fits the variables better, but at other scales in other regions, the previous model is no longer applicable. The number of variables and explanatory power of the model will change as the research area and scale change. Finally, the model cannot effectively deal with spatial autocorrelation problems (Augustin, Mugglestone, et al., 1996). A type of land use, except for being influenced by external driving factors and its own conditions, also interacts with the types of land surrounding it. In the analysis using the empirical-statistical model, there is a precondition that the data is statistically independent and the data is evenly distributed, and in practice, this assumption does not hold (Augustin, Mugglestone, et al., 1996).

(b) Conceptual mechanism model

The temporal and spatial pattern of LUCC is caused by biological natural and socio-economic processes (Turner, Skole, et al., 1995). Conceptual mechanism models often use theory and laws to simulate the operation of various processes, track their evolution, and emphasize the interaction of components in its system (Lambin, Rounsevell, et al., 2000). They simplify and synthesize complex systems into different equation forms. Therefore, the construction of models is based on the previous analysis of the causality of system changes and the understanding of land use individual behaviour or social group behaviour. Different from the empirical-statistical model, it is a deductive, theoretical, process-based model that can be used as a general theory to explain LUCC and guide the formulation of various policies (Overmars and Verburg, 2007).

Popular with LUCC modellers, but such models still have drawbacks and limitations. Many economic land use models are premised on the knowledge of landowners who make decisions based on the expected benefits or utility maximization (Ruben, Moll, et al., 1998). Most models can only simulate simple, ideal conditions. Insufficient consideration of the social system factors affecting land use often results in the model being away from reality, lack of scientific and persuasive, and reduced predictive. Second, the model requires a high level of data, especially a multi-agent model. The main challenge of this type of model is how to obtain sufficient data at the individual or other levels to develop a parametric model of subject decision making (Verburg, Schot, et al., 2004).

2.1.4 Urban Ecosystem Services

The urban environment is an exclusive artificial ecosystem established by human beings based on the natural environment. The urban population interacts with the urban environment (biological and non-biological elements) to form a complex network system (Min, Yuehua, et al., 2002). The urban can be considered as a single ecosystem or combined with several independent ecosystems (Rebele, 1994). In the early 20th century, Geddes applied the principles of ecology to the comprehensive planning of urban environmental, municipal, and health research in the book Cities in Evolution. Geddes' goal is to introduce nature into the city, emphasizing the planning of a harmonious approach to nature in accordance with the natural potential and constraints in the planning process (Geddes, 1949). Urban ecosystem refers to the area where human beings live intensively, or buildings and various artificial infrastructures occupy an enormous area of terrain (Pickett, Cadenasso, et al., 2001). Urban ecosystems offer diversity services and improve resilience to shocks (Gómez-Baggethun and Barton, 2013). Elmqvist and Fragkias said: “Ecosystem services refer to the benefits that humans derive from the ecosystem” (Elmqvist, Fragkias, et al., 2013). Correspondingly, urban ecosystem services refer to the profits that humans draw on urban ecosystems (Bolund and Hunhammar, 1999). According to Elmqvist and Fragkias (2013) said: “Most of the ecosystem services consumed by cities come from ecosystems outside the city”. In cities with large populations and huge resource consumption, most of the urban ecosystem services (Hereinafter referred to as UES) they need are derived from other ecosystems in the surrounding or remote areas (Bolund and Hunhammar, 1999).

UES can be seen in two dimensions. Since it is a service, there will be “goods” and “services” for the service. “The Millennium Ecosystem Assessment” (2005) and “the Economics of Ecosystem Services and Biodiversity” (Kumar, 2010) classified “goods” in the UES. From MEA (2005) perspective, UES can be classified as four categories(see Table 1 below for details). Two classifications stand on a different perspective on UES, classification of MEA is now the mainstream classification. De Groot et al. (2012) further classified four types as “provisioning services, regulating services, habitat services, and cultural services”.

Table 1: Classification of Urban Ecosystem Services

Classification	Explanation	Services
Provisioning Services	goods obtained from ecosystems	Food Fiber Genetic resources Bio-chemicals, natural medicines, etc. Ornamental resources Fresh water
Regulating Services	regulating services: benefits obtained from ecosystem processes	Air quality regulation Climate regulation Water regulation Erosion regulation Disease regulation Pest regulation Pollination
Cultural Services	intangible benefits from ecosystems	Cultural diversity Spiritual and religious values Recreation and ecotourism Aesthetic values Knowledge systems Educational values
Supporting Services	ecological functions underlying the production of ecosystem services	Soil formation Photosynthesis Primary production Nutrient cycling Water cycling

Ecosystems provide almost all elements of human well-being. The most basic food and energy needs of residents depend on the provisioning of natural ecosystem services (Li, Y., Lin, et al., 2012). And the improvement of living conditions is subject to the supply of ecosystem services (Li, Y., Lin, et al., 2012). Fisher and Turner (2008) proposed that the main characteristics of UES are multi-functional. UES are ecological processes in nature which provide important inputs to change human well-being (Fisher and Turner, 2008). Any ecological processes that make any change of human well-being can be seen as services (Fisher and Turner, 2008).

In addition to the feature mentioned above, UES has the following characteristics:

(a) Human-oriented: the urban ecosystem is a complex system dominated by people. While influencing and changing ecosystem services, people are also the ultimate beneficiaries of ecosystem services (Duzheng, Congbin, et al., 2001).

(b) Huge demand: The dense of the population in the city and the limited natural resources are strongly disturbed by human activities. However, maintaining the operation of the city requires a variety of ecosystem services (Brander and Koetse, 2011).

(c) Socio-economic attributes: The provisioning and demand for UES are closely related to the socio-economic status of residents. Studies have shown that there is a significant correlation between the income level of urban residents and the biodiversity of the surrounding environment, green space coverage, and management intensity of green space (Tratalos, Fuller, et al., 2007).

(d) Dis-service of ecosystems: While urban ecosystems provide services to residents, they also cause inconvenience and potential harm to humans, which can be called the negative effects of ecosystems (dis-service) (Lyytimäki, Petersen, et al., 2008). The valuation should take into account both the benefits of ecosystem services and the cost of ecosystem damage (Gómez-Baggethun and Barton, 2013). In the study of UES, it is necessary to objectively evaluate the losses and harms caused by the negative effects of urban ecosystems.

(e) Dynamics: Land use types, population growth, and economic growth brought about by rapid urban expansion directly or indirectly affect and change UES. Affected by human activities, the magnitude and intensity of changes in UES are much greater than in other regions.

2.1.5 Functions of urban ecosystem services

Ecosystem service functions can be roughly divided into two categories (Zhuyun, Jiaoke, et al., 1999), One is ecosystem products, such as food supply for human beings, industrial raw materials, medicine and other commercialized functions, which are of direct value. The other is to support and maintain the environment that human beings depend on for survival, such as climate regulation of ecosystem, water regulation, soil and water conservation, soil fertility renewal and maintenance, nutrient recycling, carbon dioxide fixation and other functions that are difficult to be commercialized, which are shown as indirect value.

Although the indirect value of ecosystem service functions is not reflected in the national accounting system, the indirect value greatly exceeds the direct value, and the direct value often originates from the indirect value (Zhuyun, Jiaoke, et al., 1999). The indirect value of ecological service system includes the following contents:

(a) Solar fixation. Plants fix solar energy through photosynthesis, allowing it to enter the food chain, providing life support for all species, including humans.
(b) Climate Regulating. Ecosystems regulate both the atmosphere and local climate, including the effects on temperature, precipitation and airflow, thus mitigating the adverse effects of extreme weather on humans.
(c) Water regulation. Well-developed vegetation in the catchment area has the effect of regulating runoff. The roots of the plant penetrate deep into the soil, making the soil more permeable to rain. The vegetation has a slower and more uniform runoff than the bare land. Generally, the rainy season can be weakened during the rainy season in the forest cover area, and there is still water flowing in the river during the dry season.
(d) Erosion control and sediment retention. Prevention of loss of soil by wind, runoff, or other removal processes, storage of stilt in lakes and wetlands.
(e) Nutrient cycling. Organisms obtain essential nutrients from soil, atmosphere and precipitation to form living organisms. All living organisms in the ecosystem store various nutrient elements, and through the circulation of elements, promote the exchange of elements between living and abiotic environments and maintain the ecological process.
(f) Genetic resources. Ecosystem functions include pollination, gene flow, reproductive functions of cross-fertilization, and interactions between organisms and between organisms and the environment, which are of great significance for maintaining evolutionary processes and environmental benefits.
(g) Absorption and decomposition of pollutants. Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds.
(h) Entertainment, aesthetics, sociocultural science, education, spiritual and cultural values for the natural environment

2.1.6 Evaluation of urban ecosystem services

At present, the main evaluation methods of UES are index evaluation method, value evaluation method and model simulation method. Filtrating the evaluation indicators of UES is an important prerequisite for value evaluation and model simulation. The value evaluation method based on the index evaluation method, especially the monetary value evaluation method, can better quantify the UES. The model simulation method, based on the indicator evaluation and the value evaluation method, can be combined with data to predict and simulate the impact of programs on UES development.

(a) Indicator evaluation method

The indicator evaluation method is an important premise and basis for UES evaluation. Establishing eco-system service indicators that are transformable, operational, and integrateable can not only provide effective information for urban planning and nature conservation but also promote multi-disciplinary comparative research on urban ecosystem services (James, Tzoulas, et al., 2009). The evaluation of UES by the indicator method is widely used all around the world, such as Gainesville, US (Dobbs, Escobedo, et al., 2011), Greater Manchester, UK (Radford and James, 2013) and Vienna, Austria (Sanon, Hein, et al., 2012),etc. Due to different evaluation purposes and contents, variances in available data, and diverse research scales, the selection of indicators for UES evaluation and research in different regions often disagrees greatly and deficiencies comparability. Here, the common indicators of UES evaluation and some case study are listed (as shown in Table 2 below).

Table 2: Indicators of urban ecosystem services

Types of Services	Services Content	Indicators	Case Study
Supporting	Biodiversity	Shannon diversity and evenness index	Gainesville, US (Dobbs, Escobedo, et al., 2011)
	Pollination	Extent/abundance and diversity of flowering plants and Variety in colour	Greater Manchester, UK (Radford and James, 2013)
	Soil Quality	Soil fertility, Soil bulk density and Soil nutrients	Gainesville, US (Dobbs, Escobedo, et al., 2011)
Provisioning	Food Production	Sum of the area with cereal, vegetable and potatoes	Vienna, Austria (Sanon, Hein, et al., 2012)
Regulating	Water Flow Regulation	Maximum potential rainfall retention	Greater Manchester, UK (Radford and James, 2013)
	Storm Protection	Tree Structure	Gainesville, US (Dobbs, Escobedo, et al., 2011)
	Noise Buffering	Noise level and Physical barrier to prevent noise	Greater Manchester, UK (Radford and James, 2013)
Cultural	Recreation	Number, type and quality of recreational facilities	Greater Manchester, UK (Radford and James, 2013)

In order to better plan and manage UES, it is important to choose the evaluation indicators reasonably. Researchers have proposed some important criteria for the selection of indicators for UES evaluation: indicators that can be continuously provided, such as the maximum biomass that can be unceasingly harvested in grassland, the daily or annual tourist capacity of the tourist area (De Groot, Rudolf S., Alkemade, et al., 2010).

Selecting the threshold indicators directly related to UES, such as the specific vegetation type that precisely regulates the area required for water flow, how much green space is needed to protect a certain species, how much sputum is needed to decompose animal manure, and how many bees are needed to maintain normal plant pollination (Kontogianni, Luck, et al., 2010).

Indicators Selected can comprehensively characterize urban biodiversity and UES, such as urban diversity index (Haase, Schwarz, et al., 2012).

Based on the existing case study, I think there should be another important criterion that is linked to the composition of indicators for ecosystem services, such as biomass, leaf area index and vegetation coverage. The indicator evaluation can objectively reflect the size of the service that the ecological process has provided by the UES to reflect the sustainability of the ecological service, but it is difficult to use a comprehensive indicator to express the various service functions.

(b) Value evaluation method (will be used in Chapter 3&4)

Economic values include direct economic value evaluation and indirect economic value evaluation (Gómez-Baggethun and Barton, 2013). Such as provisioning services which have market value can directly calculate its direct economic value through monetization, while other types of services can be calculated through indirect economic value (Gómez-Baggethun and Barton, 2013). The indirect economic value evaluation method of UES mainly includes such as “contingent valuation method” (CVM), “avoidance cost method and hedonic pricing”, etc. (De Groot, Rudolf S., Alkemade, et al., 2010).

Spiritual demands, culture, and aesthetic values in social and cultural values are difficult to measure by monetary value. The evaluation method mainly relies on qualitative evaluation, construction level or general explanation (Chan, K. M., Satterfield, et al., 2012). The quantitative evaluation also generally combines the hierarchical evaluation and scoring method to measure the social and cultural value of UES. The selection of quantitative indicators requires detailed demonstration by experts, establishment of indicator principles and full consideration of regional characteristics (Radford and James, 2013).

The insurance value of UES refers to the ability to withstand disasters such as famine, floods and heatwaves (Gómez-Baggethun and Barton, 2013). The reduction in the insurance value of UES will not only bring huge economic losses but also bring economic pressure to the bounce back and reconstruction after the disaster. The current evaluation of the insurance value of UES is often associated with the evaluation of the elasticity and vulnerability of UES. The evaluation of the value of insurance allows people to manage UES well, such as setting up forests to prevent erosion or protecting coral reefs to prevent extreme storms from affecting humans (Assessment, 2005).

The evaluation of the UES value, especially the monetization value, makes people intuitively recognize the importance of UES and raise awareness of nature protection. More importantly, evaluating the value of UES can provide more information to city planners. For example, in the process of land use change, the loss of various UES and its direct or indirect economic losses should be fully considered. It is important to take advantage of the government's investment in urban green infrastructure and scientifically evaluate the priority location of building new communities (Ring, Hansjürgens, et al., 2010).

The value evaluation mainly reflects the overall scarcity evaluation of UES, which is very effective for alarming the world. However, the evaluation method needs to be perfected in theory, and the results are subjective and random. So, although not very accurate, it is good for decision makers to evaluate and judge. In contrast, it is more meaningful to use the indicator evaluation with a larger spatial scale. In the evaluation process, it is essential to consider the spatial scale of the ecosystem or the purpose of evaluation to select the method.

(c) Model simulation method

The model evaluation method, based on the indicators and value evaluation methods, visualize the extent and impact of human activities on the ecological environment. The current model evaluation for UES is Urban forest effects (referred to as UFORE or i-Tree), Social values for ecosystem services (SolVES for short) and benefits of urban green spaces (GUGS for short).

The “i-Tree model” was developed by “USDA (United States Department of Agriculture-Forest Service)”. And it is based on urban forest vegetation survey, comprehensive information on air pollution, meteorology and climate, quantify the structure and value of urban forests, and assess UES such as carbon sequestration, atmospheric pollutant absorption, cooling and energy conservation, and plant VOC emissions effect (David J, N., et al., , 2009).

SolVES model was developed by the United States Geological Survey in collaboration with Colorado State University. And it is based on GIS tools to quantify and spatialize the social value of UES (e.g. aesthetics, recreation and education, etc.) (Sherrouse, Clement, et al., 2011). The social value evaluation of the model is derived from the public's survey of attitudes and preferences for UES and is important for the evaluation of cultural services in urban. With the increasing attention of UES evaluation to social and cultural values, SolVES model has broad application prospects in the future.

BUGS was developed by the European Union, the model mainly assesses the impact of urban green space and residential patterns on urban environmental quality and human well-being (De Ridder, Adamec, et al., 2004). The model evaluates the impacts of urban green space on “traffic flow, emissions, air quality, microclimate, noise, accessibility, economic efficiency and social welfare”. And it proposed the concept of designing and arranging green spaces in urban planning, from the scale of individual streets, parks and regions. Compared with the previous evaluation model, the BUGS model emphasizes the combination of UES evaluation and planning and management (De Ridder, Adamec, et al., 2004). Although the application of this method is not abroad, it has important demonstration role for the application of UES evaluation in urban planning.

2.1.7 Evaluation of Relationships between Urban Ecosystem Services

Similar to other ecosystem services research, how to accurately quantify and express the relationship between different ecosystem services in urban is also a hotspot and a difficult point in current UES research. It is mainly divided into the following three methods:

(a) Constructing a relationship model

Deep understanding of the process and function of UES is the premise of evaluation of the relationship between different types of UES and constructing the relationship model between ecosystems for further verification and application. As Setälä (2014) pointed out: due to the competition of space and resources by different human demands of the city, there may be a linear negative correlation between different types of UES (such as developing playgrounds and reducing green area). In UES, human intervention in the ecosystem can weaken the linear negative correlation between the two UES, and instead form a nonlinear negative correlation (Setälä, Bardgett, et al., 2014). For example, while building a playground, it is possible to retain large areas of green space and increase entertainment facilities as much as possible, reducing the sharp contradiction between cultural services and support services and regulating services. This has positive implications for optimizing multiple UES.

(b) Status Evaluation

Based on the evaluation results of different UES in the current city, the status evaluation is a method to explore the relationship between types of UES (Larondelle and Haase, 2013). For example, Larondelle (2013) analyzes the UES of many cities in Europe by using the indicator method. It is concluded that the urban impervious layer area has a positive correlation with the urban climate regulation capacity. The main reason is that the urban central area usually has larger arbour trees. And the relationship between the two is different in different cities and different scales. In addition, the relationship between services can be visually displayed by spatial mapping of different current UES (Ruijs, Wossink, et al., 2013).

(c) Scenario Evaluation

Based on mechanisms affecting different UES (such as land use change, landscape pattern, government decision-making, climate change), scenario evaluation is a type of method for constructing different target scenarios and predicting changes in future UES (Nelson, Palmer, et al., 2009). For example, Viguié and Hallegatte (2012) weighed the three ecosystems of greenbelt, public transport subsidy and flood risk zoning to drive the state of UES in Paris. It is concluded that the decision to reduce urban flooding will reduce the threat of flooding to people, but it also significantly increases the daily distance travelled by car of residents; the decision to increase urban public transport subsidies will reduce the risk of driving distance and flooding, but increase the urban area; the decision to increase the green area without changing the urban area will not only increase the driving distance but also increase the risk of flood disasters. In addition, it can be combined with 3D-GIS technology to visualize the changes of different UES types and their relationships under different urban landscape patterns, providing direct information for urban planning and design (Grêt-Regamey, Celio, et al., 2013).

2.1.8 Relationship Between LUCC and Ecosystem

UES and LUCC are essentially a pair of contradictory unity and restricting each other. UES is the material basis for human survival and development, and the key of natural capital possessed by human beings. The land use process plays a decisive role in maintaining UES function (Xudong, Liding, et al., 1999). UES structure and functions are changed by land-use changes. The land is the carrier of all kinds of ecosystem, and the type of ecosystem can also be called as the type of land use. UES have different functions, because changes in land use structure cause changes in various land use types, areas and spatial positions, lead to changes in various ecosystem types, areas and spatial distribution. At the same time, land use change also changes the appearance of the natural landscape and affects the material circulation and energy distribution in the landscape (Xudong, Liding, et al., 1999). These impacts will also manifest from changes in UESV.

Different land use types will produce corresponding ecological processes, which will affect ecosystem services (Fu, Wang, et al., 2013). According to MA (Assessment, 2005): “Types of LUCC affect the main ecological processes such as energy exchange, water cycle, soil erosion and accumulation, and biogeochemical cycles, thus changing the provision of ecosystem services.” For example, cropland has a strong ability to supply agricultural products, while regulation, culture and support services are weak; natural forests have stronger regulation and support services, while product supply and service capabilities are weak. Based on the comparison of different land use types on the slope scale of the Loess Plateau, Fu (2000) found that from the top of the slope to the bottom, the land use types of “forest land-grassland-cropland” has better soil moisture and nutrient retention capacity than the “forest land-cropland-grassland” and “grassland-forest land-cropland”.

Su (2012) pointed out that “landscape fragmentation caused by the expansion of artificial land types during urbanization will have a negative impact on urban ecosystem services”. Different land use intensity has different impacts on UES (Braat, ten Brink, et al., 2008). Generally speaking, under the natural ecosystem with less human interference, the supply of service is relatively weak, but the ability to regulate and support services is strong. In the case of moderate human interference, the ability to provide services is often strong and the ability to regulate and support services is weak; when human disturbance is particularly strong, causing land degradation, the supply of various types of UES is seriously threatened (Braat, ten Brink, et al., 2008).

The land has an impact on UES, and UES has restrictions on the way the land is used: direct and indirect (Li, B., 2007). As the main way of human activities, land use is also affected by the ecological environment while affecting the ecological environment. Together, they constitute a two-way feedback relationship between LUCC and UES. Different UES have different restrictions on land use types.

(a) Direct restriction

The direct restriction is the basis of the effect, and it is also the core part of the ecological environment's restrictions on land use. It can be called "hard constraint", which is mainly reflected as a particular climate environment that directly determines the land use type. Changes in climatic factors affect the transformation of regional land use type (Li, B., 2007).

(b) Indirect restriction

Indirect restrictions are an important part of the influence and can be called as "soft constraints". Indirect constraints mainly refer to the ecological environment to achieve the constraints on the intensity of regional land use type through the human awareness changing, which is embodied in the continuous efforts of human beings to eliminate the problem of ecological environment. From the perspective of the action process, the indirect restriction manifests to lose control of the land use type, making the ecological environment problem increasingly (Li, B., 2007). After realizing the catastrophic and devastating damage caused by ecological problems, people began to recognize the importance of the ecological environment, and consciously consider the causes of the problems and the countermeasures for prevention and control, and at the same time, various policies and measures are formulated to constrain their own land use behaviours, in order to limit human land use activities within the framework of "hard constraints". Finally, as the time pass and continuous efforts, this constraint gradually showed great outcomes and ultimately led to the improvement of the relationship between land use and the ecological environment.

Thus, land use results affect the structure of UESV. LUCC is the cause of the change of UESV, and the change of UESV can, in turn, affect LUCC, resulting in the formation of new structure of land use. Because the change of UESV is also related to the unit area value, the relationship between LUCC and UESV is not simply linear, but very complex.

2.2 Conceptual Framework

LUCC and UES are important factors in the ecological environment. In this thesis, I mainly focus on the one-way impact of LUCC on UES. In particular, evaluation of LUCC types change means the following three ways: the area of change, the speed of changing and the transfer matrix; evaluation changing of urban ecosystem services value mean direct changes in the value of UES caused by changes in land use types. The way LUCC affects UES is through change of the three ways.

The conceptual framework divides 2008-2018 into two periods, 2008-2013 and 2013-2018. They will cover the planning period of two five-year plans in China (2011-2015 and 2015-2020). The policies implemented in the two periods are different. People pay different attention to the urban ecosystem service, Wuhan's economic development speed is also different, and the two periods will have a clear contrast.

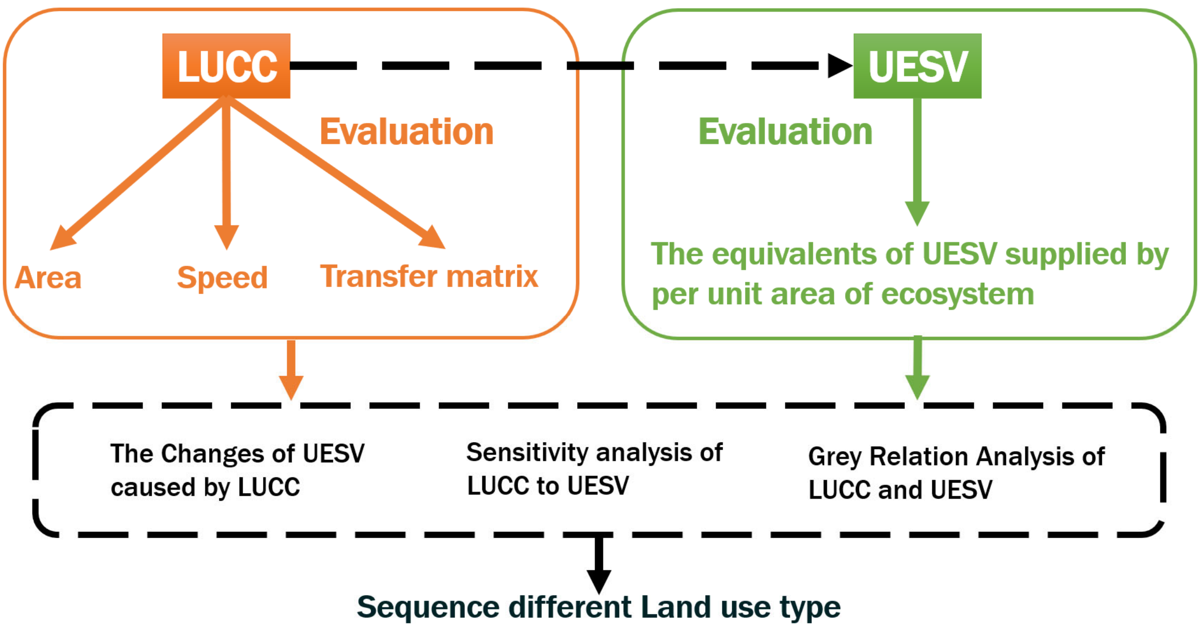
In order to research how LUCC have impacts on UES requires three steps.

Firstly, the evaluation of LUCC is needed, which is the area of LUCC, the change rate of LUCC and the transfer matrix. The changing area of land use type will show the most visual change in land area, which will be depicted by GIS map. The change rete of LUCC is to calculate the change rate of a single land use type to analyse the intensity of its change in a certain period. For the transfer matrix, it can not only reflect the structure of land use types at the beginning and end of the study but also reflect the transfer and change of land use types during the study period. It is helpful to understand the loss direction of each land use type at the beginning of the study and the source and composition of the land use type at the end of the study.

And the second step is to calculate the values of UES before and after the LUCC during 2008-2018. The urban ecosystem services value can be calculated from the change of the total value and the change of single functional Wuhan's UES. The former will start from the perspective of each type of land use and demonstrate the impact of changes in land use types on total value. The latter will show that in these impacts, the function of each urban ecosystem service is affected.

The third step is to calculate to what extent that UESV change caused by the LUCC with the model, sensitivity analysis and the grey relation analysis. Sensitivity analysis is to verify the correspondence between ecosystem types and land use types and the accuracy of the value coefficient. The value of coefficient less than 1 indicates that the coefficient is applicable in the case of Wuhan, and the smaller the representation, the more accurate. The calculation process of the grey relation analysis is relatively complex, so the data processing system is used to calculate it. Finally, it can be shown that two groups sequence of influence of land use types in Wuhan's urban ecosystem value in two time periods.

Figure 1: Conceptual framework



Chapter 3: Research Design and Methods

This chapter will cover the calculation method of evaluation in the theoretical framework and take the research from theory to practical operation.

Firstly, after the literature review in Chapter 2, the research questions are revised and combined with land use changes, UESV and its functions mentioned in Chapter 2. Then describe the research strategy and why it was chosen. Next, I will explain how to research the collected data with the research method and explain the meaning of the indicators in the research. Finally, the calculation formula, value coefficient and analysis method used in this paper are introduced. In addition, the data collection and sample city of Wuhan will be explained.

3.1 Revised research question

Just as what Chapter 1 and Chapter 2 said, this thesis focuses on the impact of LUCC type changes on UES. Changes in land use types affect the main ecological processes such as energy exchange, water cycle, soil erosion and accumulation, and biogeochemical cycles, thus changing the provision of ecosystem services (Assessment, 2005). For example, cultivated land has a strong ability to supply agricultural products, while regulation, culture and support services are weak; natural forests have stronger regulation and support services, while product supply and service capabilities are weak. Su (2012) pointed out that landscape fragmentation caused by the expansion of artificial land types during urbanization will have a negative impact on UES. Different land use intensity has different impacts on UES (Braat, ten Brink, et al., 2008). Generally speaking, under the natural ecosystem with less human interference, the supply of service is relatively weak, but the ability to regulate and support services is strong. In the case of moderate human interference, the ability to provide services is often strong and the ability to regulate and support services is weak; when human disturbance is particularly strong, causing land degradation, the supply of various types of UES is seriously threatened (Braat, ten Brink, et al., 2008). In these impacts, there are changes that can increase UES value and decrease UES value. This also means that different land use types have different impacts on urban ecosystem services. When the land use type changes, their urban ecosystem services value will also change, and the value of different functions in UES will change as well.

If the development of land use types that can increase the urban ecosystem services value is appropriately increased in the process of urban development, and the development of land use types that reduce the urban ecosystem services value is reduced, the urban ecosystem services value will eventually be steadily increased in urban development.

The research will find out which kind of land use type change had the most impact on the value of urban ecosystem services in Wuhan during 2008-2018?

Box 3: Revised research question

Overall research question:
“Which kind of land use type change had the most impact on the value of urban ecosystem services in Wuhan during 2008-2018？”

Specific research questions:

1. **What changes happened to the land use types of Wuhan during 2008-2018?**
2. **To what extent has Wuhan's UESV changed during 2008-2018?**
3. **How does the change of LUCC in Wuhan explain the change of UESV in Wuhan during 2008-2018?**

3.2 Research strategy

(a) Desk research

This research requires a relatively long period——10 years trend of the land use type. It is necessary to collect the current land use type and compare it with the land use type ten years ago. Desk research will enable study trends over time. The current data is available and can be measurable. However, due to the changing that happens on the land use types are all the times, the previous data is no longer measurable. Secondary data is a reliable source for the historical data about land use type change within a city. Because this is the officially measured annual data of land use types, after several years, it has been cited and studied by many scholars. And it has been researched and verified in terms of reliability. And desk research can provide a reliable basis for current data collection.

(b) Case study

According to Van (2014): “the research involves extremely labour intensive and protracted processes, which place high demands on the researcher” (Van Thiel, 2014). Therefore, internal validity will increase. The LUCC type changes’ situation of Wuhan is largely influenced by time and location. On one hand, the change of LUCC types are restricted by the land type itself, for example, the land use type of some waters cannot be changed to built-up area of forest land. On the other hand, affected by the driving force of urban development, some of the original greening lands had to be rapidly changed to built-up area in a short term in order to develop the economy of the urban. Case studies can be used to see the evolution, trends, and effects of Wuhan in this space and time, which allow the research to discover the relationship between the LUCC type change and the change of UES value.

Wuhan is a special city in China with a unique geographical location and economic status. The research is to study the relationship between land use types and UES in Wuhan. There are many complex variables in the research that are unique in this case. Variables include changes in land use types across time and space. During the ten years of change, there are factors of human activities, economic development, local policies, which cannot be copied and generalized.

3.3 Operationalization: Variables, Indicators

Table 3: Variables & Indicators of LUCC& UES& UESV

Sub question	Concept	Variables	Indicators	Data type	Data resources	Method
1. What changes happened to the land use types of Wuhan during 2008-2018?	Land use type change	Net change area of single land use type	Cultivated land (km^2); Forest land (km^2); Grass land (km^2); Surface water body (km^2); Built-up area (km^2); Vacant land (km^2)	Quantitative	Secondary	GIS/ Regional municipality
		The annual rate of change in land use types	Annual rate (%)	Quantitative	Secondary	GIS/ Regional municipality
		Dynamic degree of land use type	The intensity of land use change			
		Transfer matrix	Transfer of land use types (km^2)			
2. To what extent has Wuhan's UESV changed during 2008-2018?	Value of UES	The ecological service value per unit area in UES	Air quality maintenance (¥/(km^2); Climate regulation (¥/(km^2); Water regulation (¥/km^2); Soil formation and Erosion control (¥/km^2); Waste treatment (¥/km^2); Biodiversity (¥/km^2); Food production (¥/km^2); Raw material provision (¥/km^2); Entertainment culture (¥/km^2);	Quantitative	Secondary	GIS/ Regional municipality
3. How does the change of LUCC in Wuhan explain the change of UESV in Wuhan during 2008-2018?	Sensitivity analysis	Paired change area of land use type	Coefficient of sensitivity	Quantitative	Secondary	GIS/ Regional municipality
	Grey Relevant Degree Analysis	grey relevant coefficient	grey relevant degree			(DPS) Data Processing System

3.4 Data Collection & Sample Size and Selection

This part of the thesis is the collection of the data. The data is secondary data were collected by consulting landscape photo database, soil, vegetation and hydrological data form Wuhan Natural Resources and Planning Bureau and Wuhan Municipal Bureau of Statistics (during the fieldwork period,) and summarized the yearbook. Finally, the area data of various land use types in 2008,2013 and 2018 at three-time nodes during this decade are obtained and tabulated. The reasons for the selection of the case Wuhan and its basic introduction were introduced in 3.4.2.

3.4.1 Data Collection

Secondary data: Net change area of single land use type will be collected from "Wuhan City Statistics Bureau Yearbook". And the data will cover the range from 2008 to 2018. Refer to the field survey data of Wuhan from 2008 to 2018 (including landscape photo database, soil, vegetation and hydrological data of the survey site). Based on the completeness of existing data, the land use type situation of Wuhan is analysed by using thematic map image statistics data in 2008, 2013 and 2018. And GIS will also be used in mapping the change in land use types. The basic data of land use types and their changes in Wuhan are summarized in Table 4.

Table 4: Land Use Data of Wuhan

Land Use Types	Cultivated land	Forest land	Grass land	Surface Water Area	Built-up area	Vacant land
2008 Area (km²)	5103.05	792.57	67.92	1744.62	793.35	73.1
Percentage of total area (%)	59.51	9.24	0.79	20.35	9.25	0.85
2013 Area (km²)	4761.18	781.67	77.62	1835.37	1053.68	65.09
Percentage of total area (%)	55.53	9.12	0.91	21.40	12.29	0.76
2018 Area (km²)	4368.88	1320.15	70.85	1436.78	1366.03	9.65
Percentage of total area (%)	50.96	15.40	0.83	16.76	15.94	0.11

3.4.2 Sample Size and Selection

China's regional terrain is very complex, it is one of the most active areas of human activities, and it is also one of the most representative areas of LUCC in the world (Wenjian, Haishan, et al., 2015). As a populous country, the per capita land resources are relatively small, but the population growth is rapid, leading to rapid changes in land resources.

Wuhan is a long-established city in China. After thousands of years of development, it has made great progress. In the past development process, the dependence on land is the root cause of human beings changing the appearance of natural ecosystems (He, Li, et al., 2015). Located in the central part of China, Wuhan is dominated by plains with a small number of low hills (Wuhan Government, 2018). "The climate belongs to the subtropical monsoon climate zone. The natural vegetation is dominated by evergreen broad-leaved and deciduous broad-leaved mixed forests. Pinus massoniana, Chinese fir and eucalyptus are common" (Wuhan Bureau of Statistics, 2018). According to the statistics of the Wuhan Bureau (2018), as of 2018, "the total resident population of Wuhan was 10.8929 million. Wuhan is located in the eastern part of the Jianghan Plain and in the middle reaches of the Changjiang River. Changjiang River and its largest tributary traverse the central part of the city, dividing the central city of Wuhan into three, forming a pattern of three towns across the rivers. The rivers and lakes are intertwined. The surface water body accounts for 25% of the city's land area, which constitutes the water environment of Binjiang Lake" (Wuhan Government, 2018).

The ecological environment of Wuhan is relatively complex among many cities in China. As an emerging development city in China, the research on the impact of types of LUCC on UES is highly representative.

3.5 Validity and Reliability

The validity and reliability of the research are guaranteed by analysis method and data source.

For validity, the variables and indicators of LUCC and UES are based on proven theory and model. More importantly, the calculation formula models used in the research are all verified and have been used for a long time. The results calculated from the land data are accurate and effective. The data has great regional characteristics and is limited by the development history and development structure space of the city of Wuhan.

For reliability, the source of land use data is the official statistics of China. After many researchers calculate and measure, the accuracy of the data is greatly guaranteed. For the collection of historical data, the official data is used instead of the model calculation. The data of each year comes from the statistical yearbook of the year, which greatly ensures the reliability of the data.

3.6 Data Analysis Techniques

Just as mentioned in the previous 2.2 Conceptual Framework, the framework of this thesis is divided into three parts. The first part is the change in land use type. In 3.6.1, four formulas to calculate the change of land use type and how they will be applied will be introduced. They are the key to calculate the area change, dynamic change, degree change and transfer matrix of land use type. In 3.6.2, the application of urban ecosystem services value calculation will be introduced, involving the Costanza's (1997) evaluation principle and method mentioned before, and based on the conditions of China, the numerical value of it will be modified on the basis of Gaodi Xie research (2003). The last part is to use the grey relevant analysis method to rank the impact degree of different land use types.

3.6.1 Evaluation of land use type

3.6.1.1 Net change area of single land use type

$$\Delta \boldsymbol{S}_{\boldsymbol{i},\boldsymbol{i}} = \boldsymbol{S}_{\boldsymbol{is}} - \boldsymbol{S}_{\boldsymbol{ie}} \tag{1}$$

$\boldsymbol{S}_{\boldsymbol{is}}$——Total area of land use type of category i at the start-year of data;

$\boldsymbol{S}_{\boldsymbol{ie}}$——Total area of land use type of category i at the end-year of data;

$\Delta \boldsymbol{S}_{\boldsymbol{i},\boldsymbol{i}}$——Net change area after the conversion of the i-type from the starting to the end of the data;

3.6.1.2 Dynamic model of land use type

The dynamic model is analysed to reflect the speed and degree of changes in land use types.

$$\boldsymbol{K_i} = \left\{\sum_{j}^{n}\left(\frac{\Delta \boldsymbol{S_{i,j}}}{\boldsymbol{S_{is}}}\right)\right\} \times \frac{\mathbf{1}}{\boldsymbol{T}} \times \mathbf{100\%} \qquad (2)$$

$\boldsymbol{K_i}$—— Dynamic degree of land use type i (Single land use type), also Annual change rate;
$\boldsymbol{S_{is}}$——Total area of land use type of category i at the start-year of data;
$\Delta \boldsymbol{S_{i,j}}$——Net change area of mutual the conversion of the i-type and other j-types from the starting to the end of the data;
T——The time period;

The annual change rate of the I land use type $\boldsymbol{K_i}$ reflects the annual change rate of the land use type in the research sample area linking to the T-time period.

3.6.1.3 Land use degree index

The land use degree index is an indicator for measuring the breadth and depth of land use. And it can quantitatively express the comprehensive level and trend of land use in an area.

$$\boldsymbol{I_j} = \sum_{i}^{n}(\boldsymbol{A_i} \times \boldsymbol{C_i}) \times \mathbf{100}, \ \boldsymbol{I_j} \in (\mathbf{100}, \mathbf{400}), \ \boldsymbol{i} = \mathbf{1}, \mathbf{2}, \mathbf{3}, \mathbf{4} \qquad (3)$$

$\boldsymbol{I_j}$—— Comprehensive index of land use type j in a certain region;
$\boldsymbol{A_i}$—— Gradation index of land use type i within the region;
$\boldsymbol{C_i}$—— Percentage area of land use type i within the region;
n——The land use degree grading index. (Vacant Land, n=1; Forest Land, Grass Land and Surface water body, n=2; Cultivated land, n=3; Built-up area, n=4);

The dynamic degree of the land use type reflects the intensity of the land use type change in the area linking to the T-time period.

3.6.1.4 Transfer matrix analysis

$$\boldsymbol{S_{ij}} = \begin{bmatrix} \boldsymbol{S_{11}} & \cdots & \boldsymbol{S_{1n}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{S_{n1}} & \cdots & \boldsymbol{S_{nn}} \end{bmatrix} \qquad (4)$$

$\boldsymbol{S_{i,j}}$——Area of mutual the conversion of the i-type and other j-types from the starting to the end of the data;
i,j——Types of land use at the beginning and end of the study;

The significance of the shift matrix of land use type is that it can both reflect the structure of land use types at the starting and end of the study and reveal the LUCC types during the research period. It is helpful to study the loss direction of each LUCC type at the starting of the study and trace of the LUCC type at the end of the research (Chan, D., 2015).

3.6.2 Evaluation of urban ecosystem services value

3.6.2.1 Evaluation of UESV

The study of Costanza (Costanza, d'Arge, et al., 1997) has clarified UES evaluation principle and method, but there are errors in some values compared with China's actual national conditions, such as the estimation of cultivated land is too low and the estimation of wetlands is too high. After the publication of the research results, the academic circles have extensively discussed from various aspects (Zhongxin and Xinshi, 2000, Howarth and Farber, 2002, Serafy, 1998). According to China's actual situation and Costanza's research results, Gaodi Xie (Gaodi, Chunxia, et al., 2003) worked out “The value of ecosystem services per unit area of China's ecosystems” seen in Table 5.

Table 5: The equivalent table of unit area ecosystem service value of China's ecosystems (RMB/km²·a)

Service Items	Forest	Grass land	Farmland	Wet land	River	Unused land
Gas regulation	30.970	7.079	4.424	15.927	0.000	0.000
Climate regulation	23.891	7.964	7.875	151.309	4.070	0.000
Water regulation	28.315	7.079	5.309	167.152	180.332	0.265
Erosion control & soil formation	34.509	17.255	12.919	15.311	0.088	0.177
Waste treatment	11.592	11.592	14.512	160.866	160.866	0.088
Biological control	28.846	9.645	6.282	22.122	22.033	3.008
Food production	0.885	2.655	8.849	2.655	0.885	0.088
Raw materials	23.006	0.442	0.885	0.619	0.088	0.000
Recreation &cultural	11.326	0.354	0.088	49.109	38.402	0.088
Total	193.340	64.065	61.143	555.070	406.764	3.714

In combination with the land use type classification adopted in this thesis, it is divided according to Table 5. When UESV is calculated, cultivated land corresponds to farmland, forest land corresponds to forest, surface water body corresponds to river, vacant land corresponds to wasteland, and built-up area adopts the research results of Ruijuan Duan et al. (Ruijuan, JinMin, et al., 2005), whose ES value coefficient is -88.521 RMB/km²·a.

In this thesis, the Costanza(1997) calculation formula is used to estimate UESV. The calculation formula is:

$$\mathrm{ESV} = \sum A_k \times V_k \quad (5)$$

$$\mathrm{ESV}_f = \sum A_k \times V_{fk} \quad (6)$$

ESV——Total value of ecosystem services (RMB);

A_k——Distribution area of land use type k in the study area (km²);

V_k—— The value coefficient of ecological services refers to the value of ecosystem services of land use type k per unit area (RMB/km² • a);

ESV_f——The total value of ecosystem service function f in the study area (RMB);

V_{fk}—— The value of ecosystem service function f per unit area (RMB/km² • a);

According to the research results obtained by Table 5 and Ruijuan et al. (2005), the ecological service value per unit area of various land use types in Wuhan is obtained, and the land use type of built-up area is added, as shown in Table 6 below.

Table 6: The value coefficient of each land use type per unit area in Wuhan (RMB/km²·a)

Service Items	Cultivated land	Forest Land	Grass land	Surface water body	Built-up area	Vacant land
Gas regulation	4.424	30.970	7.079	0.000	0.000	0.000
Climate regulation	7.875	23.891	7.964	4.070	0.000	0.000
Water regulation	5.309	28.315	7.079	180.332	-66.780	0.265
Erosion control & soil formation	12.919	34.509	17.255	0.088	0.000	0.177
Waste treatment	14.512	11.592	11.592	160.866	-21.741	0.088
Biological control	6.282	28.846	9.645	22.033	0.000	3.008
Food production	8.849	0.885	2.655	0.885	0.000	0.088
Raw materials	0.885	23.006	0.442	0.088	0.000	0.000
Recreation &cultural	0.088	11.326	0.354	38.402	0.000	0.088
Total	61.143	193.340	65.065	406.764	-88.521	3.714

3.6.2.2 Sensitivity analysis of UESV

In order to verify the representability of the correspondence between ecosystem types and land use types and the accuracy of the value coefficient in 3.6.2.1, analysis use the concept of elasticity coefficient which is commonly in economics (Kreuter, Harris, et al., 2001) was used to calculate the Coefficient of sensitivity (CS), to determine the degree of dependence of UESV on the value coefficient over time.

Coefficient of sensitivity refers to the ratio of the percentage of dependent variable to the percentage of independent variable: if CS>1, it indicates that the change of 1% of the independent variable causes the change of the dependent variable to be more than 1%; on the contrary, if CS<1, the change of 1% of the independent variable causes the change of the dependent variable to be less than 1% (Qiong, 2006).

The coefficient of sensitivity (CS) of the value coefficient of ecosystem services is calculated as follows:

$$\boldsymbol{CS} = \left| \frac{(\boldsymbol{UESV_j} - \boldsymbol{UESV_i})/\boldsymbol{UESV_i}}{(\boldsymbol{VC_{jk}} - \boldsymbol{VC_{ik}})/\boldsymbol{VC_{ik}}} \right| \tag{7}$$

UESV——Total value of urban ecosystem services (RMB);

VC——Ecosystem value coefficient;

i, j——Represents the initial total value of each land use type and the total value after adjustment;

If CS>1, it means that the UESV estimated for the value coefficient is elastic; if CS<1, UESV is considered inelastic; The higher the ratio, the higher the accuracy of the value coefficient of ecosystem services.

3.6.3 Grey relevant analysis method of LUCC and UESV

As one of the analysis methods, Grey Relation Analysis method has been applied to urban land planning by some scholars. In combination with the needs of local social and economic development and relevant land control indexes, the model is used to solve the optimal value of land use structure of a certain region in the future, and to seek the planning scheme that can meet the maximum benefit (Yanli, Yuequn, et al., 2009). It has the same trial on the sample size and sample irregularity and is very convenient, there will be no difference between the quantitative results and the qualitative results (Hong and Zemin, 2000). The calculation method and steps are as follows:

First, calculate the relevant coefficient ξ_{ij} :

$$\boldsymbol{\xi_{ij}(\mathbf{t}) = \frac{\Delta_{min} + \mathbf{k}\Delta_{max}}{\Delta_{ij}(t) + \mathbf{k}\Delta_{max}} (\mathbf{t} = 1, 2, \cdots \mathbf{m})} \tag{8}$$

$\xi_{ij}(\mathrm{t})$ —— The relevant coefficient of X_j to X_i at t time;

k——Gray number in the interval [0, 1], this thesis takes k=0.5;

$\boldsymbol{\Delta_{ij}(t) = |x_i(t) - x_j(t)|}$;

$\boldsymbol{\Delta_{max} = \max_j \max_t \Delta_{ij}(t)}$;

$\boldsymbol{\Delta_{min} = \min_j \min_t \Delta_{ij}(t)}$;

Then, according to the deduced $\xi_{ij}(\mathrm{t})$ can be calculated each time the average relevant coefficient, also called as relevant degree γ_{ij}:

$$\boldsymbol{\gamma_{ij} \approx \frac{1}{m} \sum_{i=1}^{m} \xi_{ij}(\mathbf{t})} \tag{9}$$

γ_{ij}——The relevant degree of comparison sequence X_j to reference sequence X_i ;

The greater the relevant degree between X_j and X_i, the greater the influence of X_j on X_i.

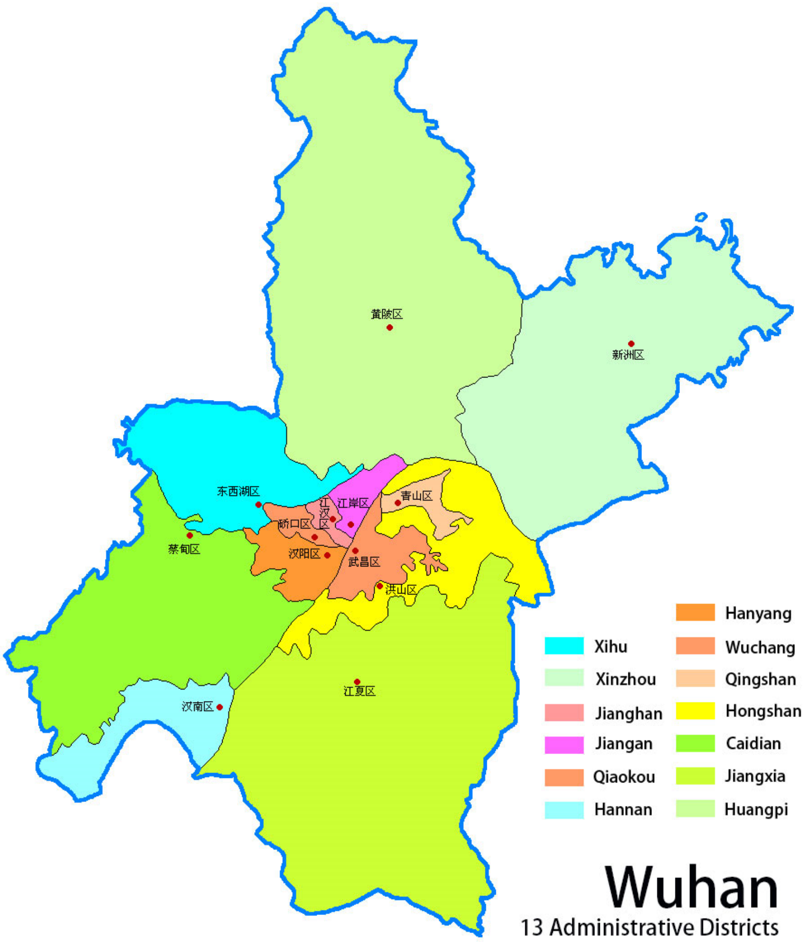
In this thesis, the grey relation analysis method combined with data processing system (DPS) software is used to calculate the degree of impact of land use type changes in Wuhan on UESV from 2008 to 2018.

Chapter 4: Research Findings and Analysis

4.1 Wuhan Overview

Wuhan is located in the east of Hubei province, at the intersection of the Yangtze River and the Han river, at longitude 113°41 '~115°05' and latitude 29°58 '~31°22'. The climate is subtropical integral humid climate, perennial rainfall is abundant, raining and hot season during the same period, most of the precipitation in June to August. There are many types of land, among which cultivated land has the largest area (Wukang, M. and Xiaoqing, C., 2018).Wuhan has 13 administrative districts, including Jianghan, Jiangan, Qiaokou, Hannan, Wuchang, Qingshan, Hongshan, Caidian, Jiangxia, Huangpi, Xinzhou, Xihu and Hanyang. In this thesis, all 13 districts with rapid urbanization in recent years were selected (See in Figure2).

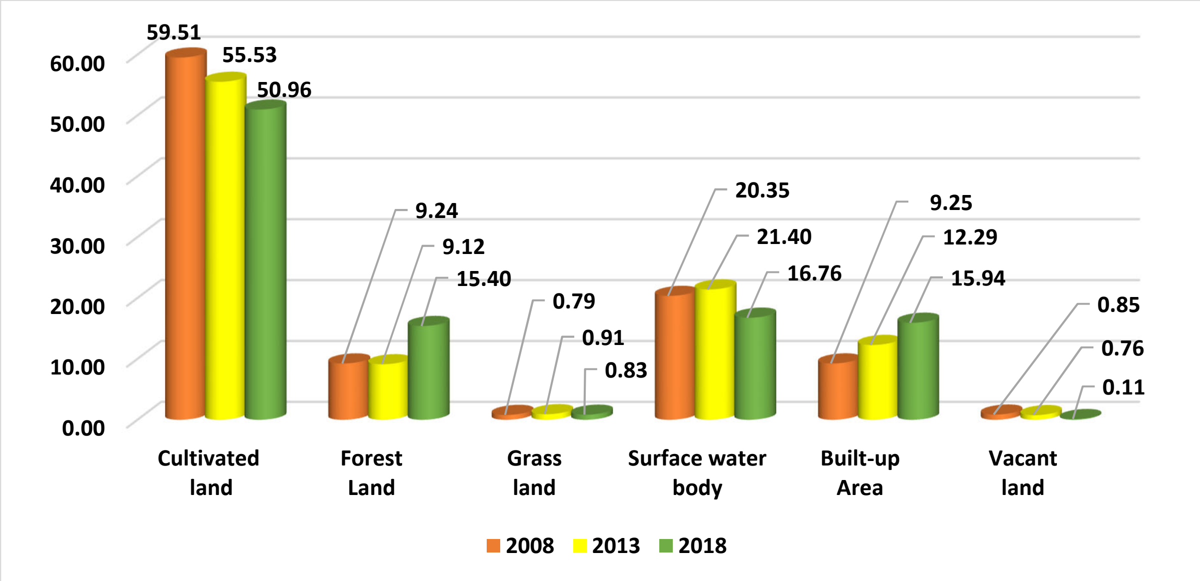
Figure 2: The 13 Administrative Districts in Wuhan



The urban ecosystem services of Wuhan are relatively complex among many cities in China. As a newly developed city in China, the research on the impact of land use type change on urban ecosystem is highly representative. The case can also be copied to Chinese city like Shanghai and Liuzhou which have rivers across the cities and with large areas of cultivated land (Built-up area is not mentioned here as a reason because this type of land accounts for a large proportion of the cities in China.).

According to table 4, the land use structure of Wuhan at three different time points can be calculated, and the results are shown in Chart 1.

Chart 1: Land Use Structure of Wuhan in 2008-2013-2018 (%)



The chart shows that the proportion of cultivated land reached 60% in 2008, which was the most important land use type at that time, followed by surface water body, built-up area and forest land, which were 20.53%, 9.25% and 9.24%. Grass land accounts for the smallest proportion, accounting for only 0.79% of the total area in 2008. By 2018, cultivated land had decreased to 50.96%, built-up area and forest land had increased to 15.94% and 15.4%, and the gap between the three types of land use gradually narrowed. Among the other three land use types, only grass land increased, while surface water body and vacant land decreased, with the proportion of surface water body decreased to 16.76% and the proportion of vacant land decreased from 0.85% to 0.11%, becoming the smallest among all land use types.

4.2 Land Use and Land Cover Changes in the Research Area

4.2.1 The Extent of Changes in the Research Area

According to the collected data of each land use type (Table 4) and formula (1), the change extent of each land type is calculated. The calculation results are shown in Table 7.

Table 7: Land Use Types Changes in Research Area During 2008-2018 (km²)

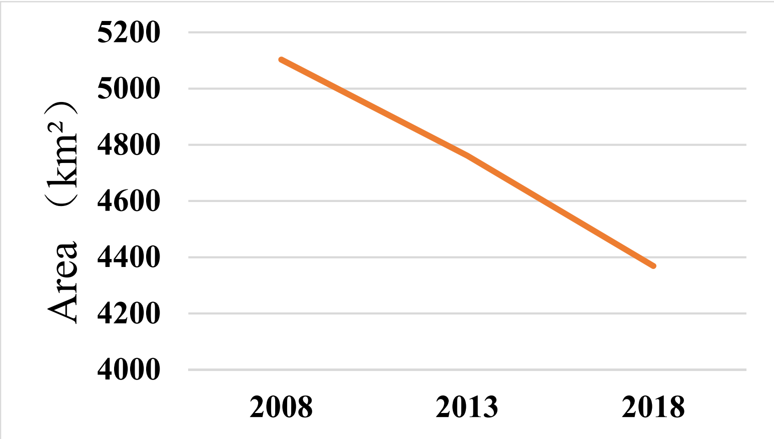
Land Use Types		Cultivated land	Forest land	Grass land	Surface water body	Built-up area	Vacant land
Area (km²)	2008	5103.05	792.57	67.92	1744.62	793.35	73.1
	2013	4761.18	781.67	77.62	1835.37	1053.68	65.09
	2018	4368.88	1320.15	70.85	1436.78	1366.03	9.65
Changes of Area (km²)	2008-2013	-341.87	-10.9	9.7	90.75	260.33	-8.01
	2013-2018	-392.3	538.48	-6.77	-398.59	312.35	-55.44
	2008-2018	-734.17	527.58	2.93	-307.84	572.68	-63.45

A comparative analysis of the LUCC data in the research area during the third period can be concluded that during the 10 years from 2008 to 2018, LUCC changes in the research area show the following characteristics:

(a) Cultivated Land

The total area of cultivated land in Wuhan has decreased by 734.17km² . Among them, the area of cultivated land in 2008-2013 decreased by 341.87km², but decreased by 392.30km²; in 2013-2018, and the rate of decrease slightly increased compared with the previous five years. However, in terms of the overall trend, the decrease in cultivated land over a ten-year period is sustained, with the decrease in cultivated land in the two five-year periods being basically the same. This is related to the government's policy of "returning cultivated land to forest" and "China's new rural construction" policy. Seen in Chart 4 below.

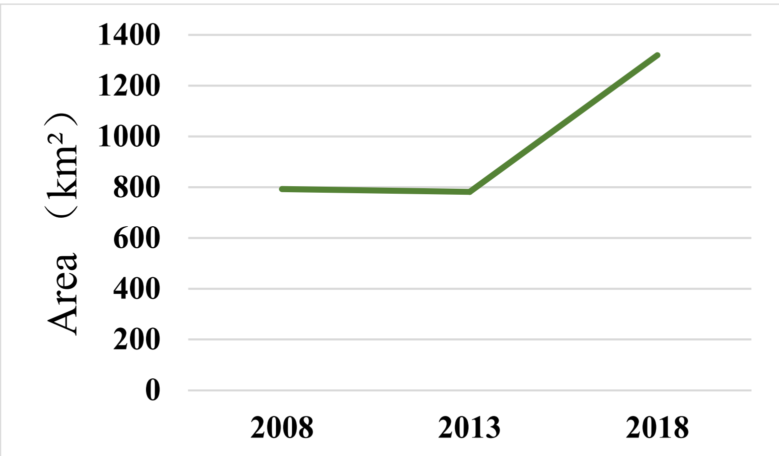
Chart 2: Cultivated land area change



(b) Forest Land

The area of forest land is generally on the rise, with a total increase of 527.58km² . Among them, the forest area in 2008-2013 showed a small decrease, the rate of change was 1.38%; the area of forest land began to increase in 2013-2018 and increased by 538.48km² during the five-year period. The government's policy on the protection of forest land ecosystems has been in effect since 2010 and is taking some time to build and restore forest ecosystems. In terms of growth trends over the 10-year period, the policy has been effective since 2010 and until 2013 the outcome showed, resulting in a sharp increase in forest land area during 2013-2018. Seen in Chart 5 below.

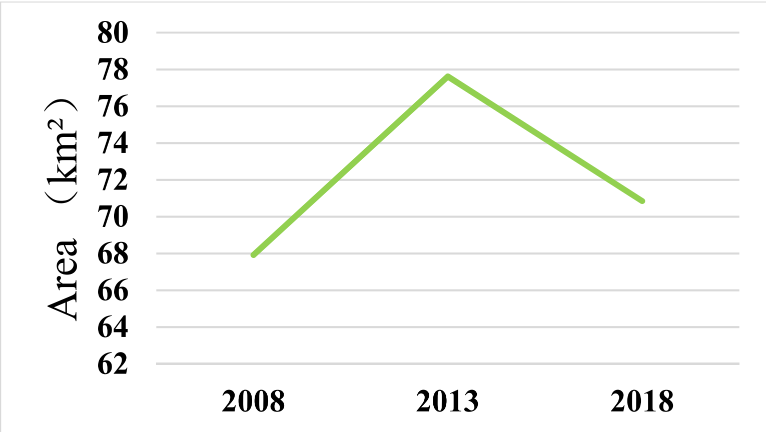
Chart 3: Forest land area change



(c) Grass Land

The change range of grass land is the smallest of all types, and the overall trend is increasing, with a total increase of 2.93km². Among them, the grassland in 2008-2013 was on the rise, increasing by 9.7km², but it was greatly reduced in 2013-2018. This is because in the rapid development of the city, grass land ecosystem is often ignored by people, and Wuhan's economic development is not dependent on animal husbandry, animal husbandry in Wuhan's GDP is only a small part (Wukang, M. and Xiaoqing, C., 2018), so the grass land ecosystem has become a victim of Wuhan's urban development. Seen in Chart 6 below.

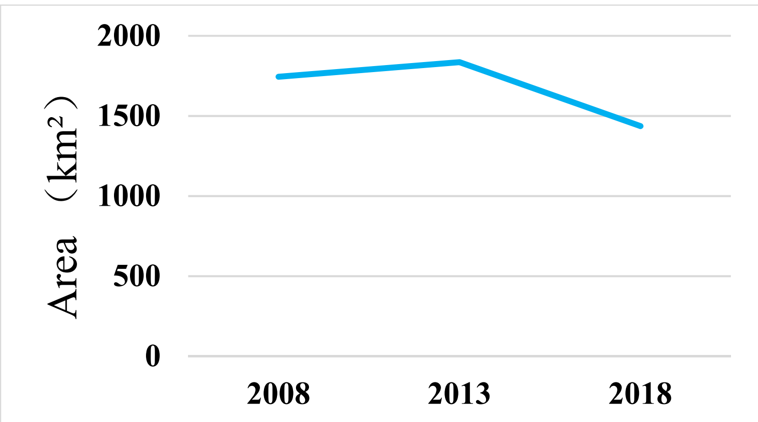
Chart 4: Grass land area change



(d) Surface water body

The total surface water body decreased by 307.84km², of which 2008-2013 increased by 90.75km², but decreased significantly in 2013-2018, the change rate was 21.72%, and the decrease was 398.59km² during the five-year period. This is because the number of ports in Wuhan has increased to 103 during this period (Overall plan for optimization and adjustment of port terminal resources in the core areas of Wuhan Yangtze River and Hanjiang River, 2018). For the economic development of the city, Wuhan has a unique advantage in the Yangtze River freight transport as a city where the two rivers meet. In addition to increasing the port on the Yangtze River Economic Belt during the period of 2013-2018, many landscape belts were established to ensure ecological balance. Both ports and landscape belts cause the declining of the surface water body. Seen in Chart 7 below.

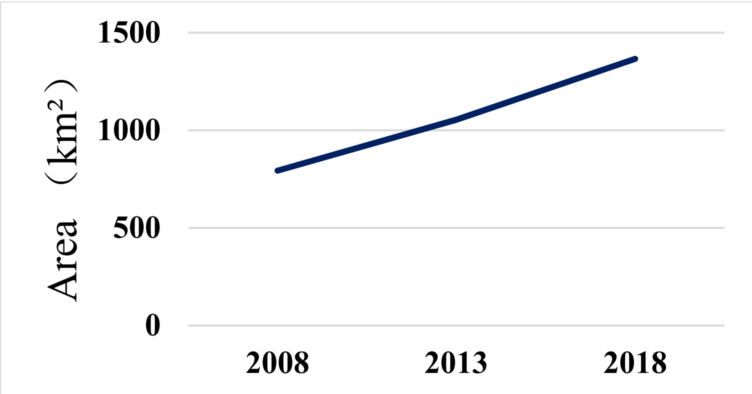
Chart 5: Surface water body change



(e) Built-up Area

The built-up area is the most increased among the six types of land use, reaching 572.68 km². The increase of the built-up area is inevitable in the stage of rapid urban development. As a booming city in China, Wuhan is under tremendous pressure to rapidly grow its economy. In the process of economic growth, the first reflection in the change in land use type is the increase in built-up area. The growth rate in the first five years is 32.81% and the growth trend in the second five years has dropped slightly, with an increase of 29.64%. The slight increase is related to the control of urban built-up area by local government. Seen in Chart 8 below.

Chart 6: Built-up area change



(f) Vacant Land

The overall extent of vacant land is decreasing, but the changes in the two periods are significantly different. In the first five years, it decreased by 8.01km², and 2013-2018 suddenly decreased by 55.44km², with a reduction of 85.17%, indicating that the utilization rate of vacant land was significantly higher than the previous five years during 2013-2018. It also reflects the fact that in the process of development of Wuhan, the demand for land in the second five years has increased sharply. No matter what type of land use is ultimately converted from vacant land, it is transformed for urban development. Explain that the city of Wuhan is booming, population migration is increasing, and land demand is increasing (Wukang, M. and Xiaoqing, C., 2018). Seen in Chart 9 below.

Chart 7: Vacant land area change

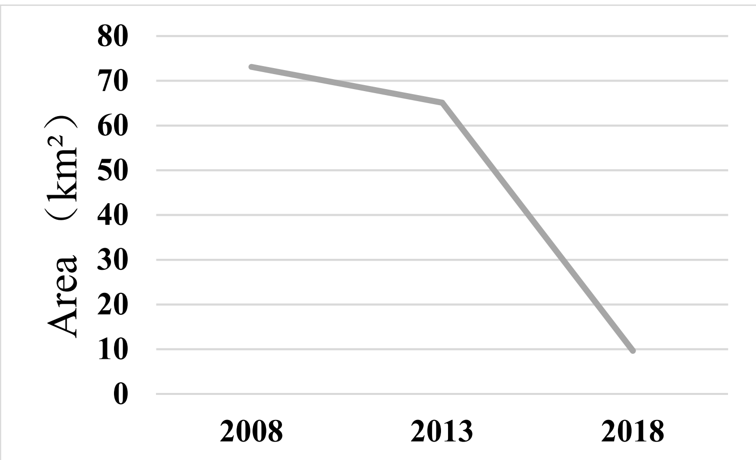
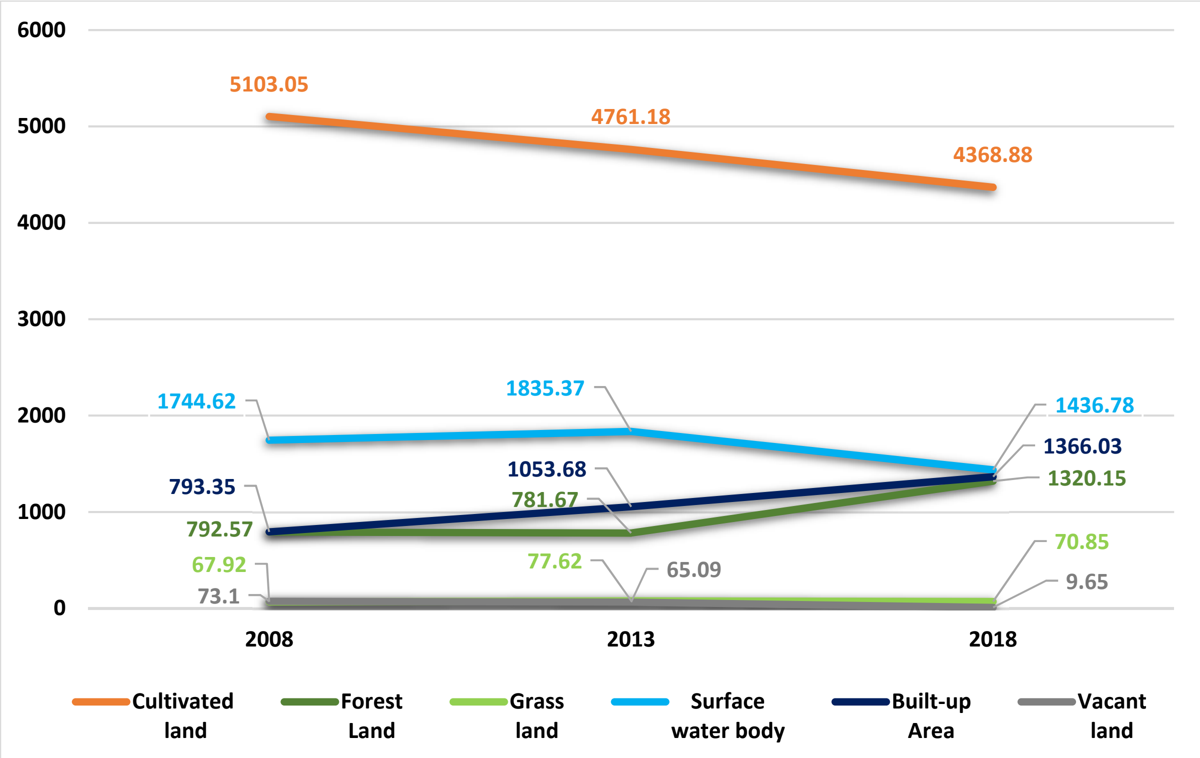


Chart 8: Areas of change in land use type change in Wuhan from 2008 to 2018 (km^2)



Through the analysis of the extent of land use changes in Wuhan, chart 8 shows that the change of cultivated land is the largest. The second reduction is in the surface water body. During this ten-years period the number of ports in Wuhan has increased to 103 during this period (Overall plan for optimization and adjustment of port terminal resources in the core areas of Wuhan Yangtze River and Hanjiang River, 2018). For the economic development of the city, Wuhan has a unique advantage in the Yangtze River freight transport as a city where the two rivers meet. In addition to increasing the port on the Yangtze River Economic Belt during the period of 2013-2018, many landscape belts were established to ensure ecological balance. This reduces the area of the water and transforms it into built-up area. The built-up area was the largest increase in all of the land use type during the 10-year period, followed by forest land. This is related to the government's policy of "returning cultivated land to forests" (Jingtao, Ran, et al., 2004)and the policy of "China's new rural construction". The change range of grass land is the smallest of all types, and the overall trend is increasing. This is because in the rapid development of the city, grass land ecosystem is often ignored by people, and Wuhan's economic development is not dependent on animal husbandry, animal husbandry in Wuhan's GDP is only a small part (Wukang, M. and Xiaoqing, C., 2018). The overall change in vacant land is not significant.

It is worth noting that at the end of the study period, 2018, the areas of surface water body, built-up area and forest land are very close. It is believed that the trend of these three land use types will have a very strong influence on Wuhan's urban ecosystem after 2018. Built-up area and forest land will continue to rise according to current trends, while the surface water body will continue to decrease.

4.2.1 The Dynamic Degree of Land Use Type Changes in the Research Area

According to the collected data of each land use type (Table 4) and formula (2), the dynamic degree of each land type is calculated. The calculation results are shown in Table 8.

Table 8: The Dynamic Degree of Land Use Types Changes in Research Area During 2008-2018 (%)

Land Use Types	2008-2013	2013-2018	2008-2018
Cultivated land	-1.34	-1.65	-1.44
Forest land	-0.28	13.78	6.66
Grass land	2.86	-1.74	0.43
Surface water body	1.04	-4.34	-1.76
Built-up area	6.56	5.93	7.22
Vacant land	-2.19	-17.03	-8.68

A comparative analysis of the LUCC data in the research area during the third period can be concluded that during the 10 years from 2008 to 2018, LUCC changes rate in the research area shows the following characteristics:

(a) Cultivated Land Change

The total cultivated land area showed a decreasing trend, the annual decline rate was 1.44%. The rate of decline in the first five years of the 10-year period was slightly lower than that in the second five years, which was higher than the average annual rate of decline of 1.44% from 2008 to 2018. The main reason is that with the increase of population and the development of urban construction, the construction of some infrastructure is intensified, occupying a large number of cultivated lands.

(b) Forest Land Change

Forest land area presents an increasing trend, on the whole, the annual increase rate is 6.66%. The change from 2008 to 2018 is divided into two stages. In the first stage, the forest land decreases slightly with a rate of 0.28%. In the second stage, the forest land increased sharply, with a growth rate of 13.78%, nearly twice the annual growth rate of forest land. Because of the social and economic development of Wuhan to a certain level, began to pay attention to forest protection, ecological construction, control of urban expansion. In 2010, China promulgated the outline of "National forest belt protection and utilization plan (2010-2020)", and Hubei province promulgated "The plan for forest land protection and utilization of Hubei province (2010-2020)". In order to implement this policy, the local government implemented "The plan for forest land protection and utilization of Caidian district in Wuhan (2010-2020)". A series of measures have been taken to protect forest land and urban ecosystems, including the project of "returning farmland to forests", "the project of protecting natural forests", "the project of building protective forests on the Yangtze River", "a comprehensive project to control the spread of the desertification rocks" and "the construction of forest parks" (Hubei Province Forest Land Protection and Utilization Planning (2006-2020), 2009).

(c) Grass Land Change

From 2008 to 2018, the grass land area showed a fluctuation trend, and the overall area increased. In the first five years, the average annual growth rate was 2.86%, which was higher than that in the second five years, the total increase is 2.93km^2 . From the overall perspective of 10 years, the change range is not big, but it can be seen that change is divided into two stages, first increasing and then decreasing. From 2013, the urban construction process was accelerated, while the city paid attention to the protection of forest land, neglected the sustainable development of grass land, which resulted in a decrease of grassland area.

(d) Surface water body Change

From 2008 to 2018, the surface water body showed the trend of fluctuation, and the overall trend is decreasing. Compared with the fluctuation of grass land, the change rate is small. From 2008 to 2013, it increased by 1.04%, slightly lower than the annual rate of change of 1.67% in 10 years, and decreased by 4.34% from 2013 to 2018, higher than the annual rate of change. The main reason is that the government has increased the intensity of ecological construction and carried out projects such as returning farmland to lakes, which has led to an increase in surface water body.

(e) Built-up area Change

The change of built-up area is the most significant change in all land types and the overall trend of continuous rise. During the ten-year period, the annual growth rate was 7.22% added 572.68km^2 . Mainly due to the rapid urban development of Wuhan during the 10 years, the city outward expansion, internal urban structure optimization and development, in order to meet the city's investment and investment in a large number of constructions.

(f) Vacant Land Change

The overall change of vacant land showed a decreasing trend, with a decrease of 63.45km^2 during the ten years. From 2008 to 2013, the average annual rate of reduction was relatively low, 2.19%; from 2013 to 2018, the average annual rate of reduction was sharply increased, 17.03%. During these five years, the degree of land use increased significantly.

In summary, among the land use types changes in Wuhan from 2008 to 2018, the built-up area increased the fastest, followed by forest land, and finally grass land. But the land area decreases fastest is the vacant land, the surface water body is the second, finally is the cultivated land.

4.2.2 The Degree Index of Land Use in the Research Area

Calculate the land use degree index of Wuhan according to Table 4 and formula (3), Seen in Table 9 below.

Table 9: 2008-2018 Wuhan Land Use Degree Index

Year	Cultivated land	Forest land	Grass land	Surface Water Area	Built-up Area	Vacant land	Total
2008	178.54	18.49	1.58	40.69	37.01	0.85	277.17
2013	166.58	18.23	1.81	42.81	49.15	0.76	279.34
2018	152.89	30.80	1.65	33.52	63.74	0.11	282.72

The value range of land use degree index is 100-400. If all land use types are vacant land, the comprehensive index of land use degree is 100; If all land use types are built-up area, then the comprehensive land use index is 400. According to the data in Table 9, the total development degree of all land use types from 2008 to 2018 is about 280, indicating that the land use degree in this research area is relatively high and has been growing continuously during the 10 years.

4.2.3 Transfer Matrix Analysis of Land Use Types in the Research Area

The transfer matrix of land use is the basis of the quantitative analysis of regional land use. The transfer matrix contains the data structure information of land use in different periods and the transformation information of various land use types in different periods. It is obtained by formula (4) and analysis of ArcGIS tools. Results seen in Table 10, Chart 9, Table 11, Chart 10 and Figure 3-5.

Through the analysis of the transfer matrix data of two periods in Wuhan, the following conclusions can be drawn:

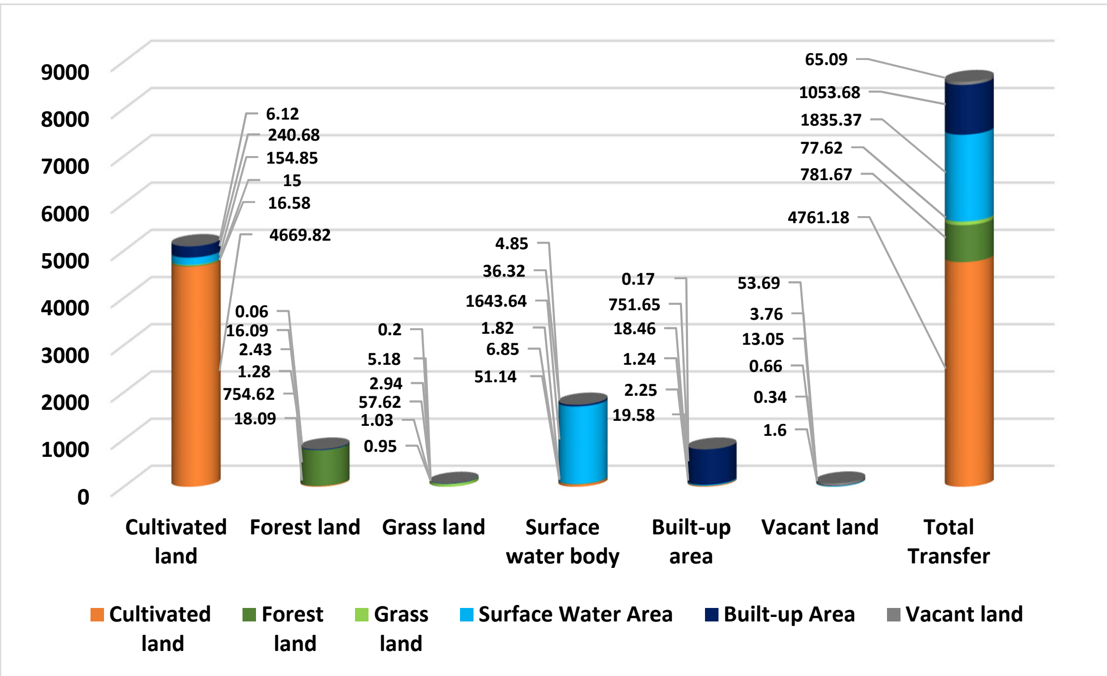
(a) Overall, cultivated land and surface water body have been declining over the past period, built-up area and forest land have been increasing, and vacant land and grass land have changed little. Since 2013, while cultivated land, grass land and surface water body have decreased, the urban built-up area has increased significantly, and urban expansion has accelerated. The decrease of cultivated land and the increase of forest land are closely related to the policy of "returning cultivated land to forest" implemented by the government. The increase of built-up area is closely related to urban expansion and development.

(b) In the context of the transformation of land use types, the transfer direction of each land use type is different.

Table 10: 2008-2013 Transfer Matrix of land use in Wuhan (km²)

Types	Cultivated land	Forest land	Grass land	Surface Water Area	Built-up Area	Vacant land	Total
Cultivated land	4669.82	16.58	15.00	154.85	240.68	6.12	5103.05
Forest land	18.09	754.62	1.28	2.43	16.09	0.06	792.57
Grass land	0.95	1.03	57.62	2.94	5.18	0.20	67.92
Surface water body	51.14	6.85	1.82	1643.64	36.32	4.85	1744.62
Built-up area	19.58	2.25	1.24	18.46	751.65	0.17	793.35
Vacant land	1.60	0.34	0.66	13.05	3.76	53.69	73.10
Total Transfer	4761.18	781.67	77.62	1835.37	1053.68	65.09	8574.61

Chart 9: 2008-2013 Transfer Matrix of land use in Wuhan （km²）



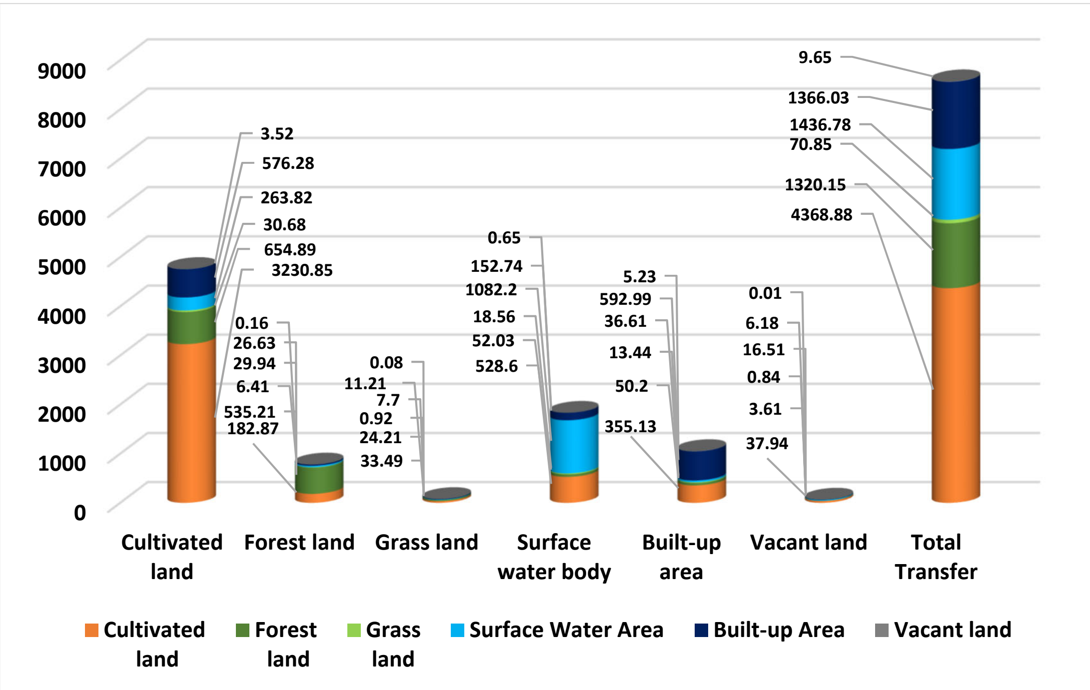
During the first five years from 2008 to 2013, a large amount of cultivated land was lost, mainly transferred to built-up area and surface water body, with the transfer area of

240.68km² and 154.85km², respectively, with the transfer rate of 3.03% and 4.72%. The forestland is mainly changed to cultivated land and built-up area, with transfer areas of 18.09km² and 16.09km², respectively, with transfer rates of 2.28% and 2.03%. The surface water body was mainly converted into built-up area and cultivated land, with a transfer area of 36.32km² and 51.14km², respectively, with a transfer rate of 2.08% and 2.93%. Under the premise of a substantial increase in the total amount of built-up area, part of it transferred to surface water body and cultivated land, with the transfer area of 18.46km² and 19.58km², with the transfer rate of 2.33% and 2.47%. The transfer of vacant land is very small, mainly for cultivated land, surface water body and built-up area, among which the largest area of surface water body is 13.05km², with a transfer rate of 17.85%.

Table 11: 2013-2018 Transfer Matrix of land use in Wuhan (km²)

Types	Cultivated land	Forest land	Grass land	Surface Water Area	Built-up Area	Vacant land	Total
Cultivated land	3230.85	654.89	30.68	263.82	576.28	3.52	4760.04
Forest land	182.87	535.21	6.41	29.94	26.63	0.16	781.22
Grass land	33.49	24.21	0.92	7.70	11.21	0.08	77.61
Surface water body	528.60	52.03	18.56	1082.20	152.74	0.65	1834.78
Built-up area	355.13	50.20	13.44	36.61	592.99	5.23	1053.60
Vacant land	37.94	3.61	0.84	16.51	6.18	0.01	65.09
Total Transfer	4368.88	1320.15	70.85	1436.78	1366.03	9.65	8572.34

Chart 10: 2013-2018 Transfer Matrix of land use in Wuhan (km²)



From 2013 to 2018, the cultivated land area continued to decrease, and the main transfer direction was from built-up area and surface water body turn to built-up area and forest land. The transfer area was 576.28km² and 654.89km², respectively, and the transfer rate was 12.11% and 13.76%. Forest land was mainly transferred into cultivated land, with the transfer area of 182.87km² and the transfer rate of 23.41%. During this period, the amount of transfer grass land was larger than that of the previous five years. Unlike other land types, a large amount of grass land was not transferred to built-up area but was mainly transferred into cultivated land and forest land. The transfer area was 33.49km² and 24.21km², respectively, with the transfer rate of 43.15% and 31.19%. The built-up area is mainly turned to cultivated land and forest land, with the transfer area of 355.13km² and 50.20km², respectively, with the transfer rate of 33.71% and 4.76%. The vacant land loss accelerated and was mainly shifted to cultivated land and surface water body, with the transfer areas of 37.94km² and 16.51km², and the transfer rates of 52.29% and 25.36%.

(c) By comparing different land use types in different periods, it can be seen that during the first five years from 2008 to 2013, a large number of cultivated land was lost, and the amount of built-up area increased sharply, while the forest land, grass land and surface water body were all mainly turned to built-up area. In the second five years from 2013 to 2018, cultivated land has been mainly shifted from surface water body to forest land. Meanwhile, compared with the previous five years, more and more built-up area has been converted into cultivated land, forest land, grass land and surface water body, which is consistent with the development process of Wuhan. Faced with serious environmental problems brought about by economic growth, national and local governments have taken measures to restore the environment, protect natural resources and limit the immoderation expansion of cities.

Figure 3: GIS Map of Land Use Types in Wuhan at 2008

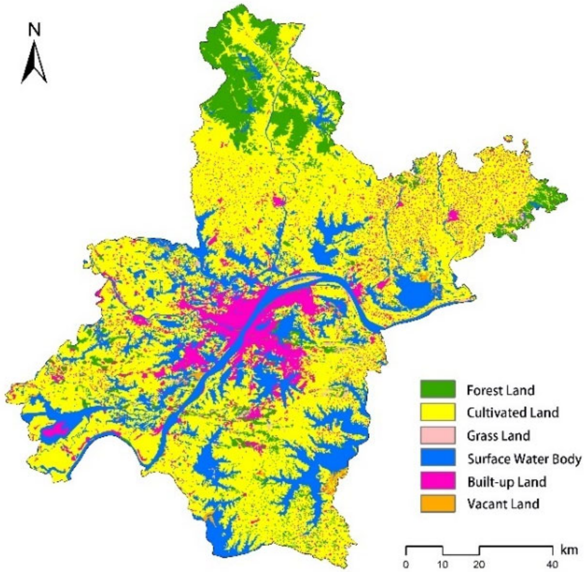


Figure 4: GIS Map of Land Use Types in Wuhan at 2013

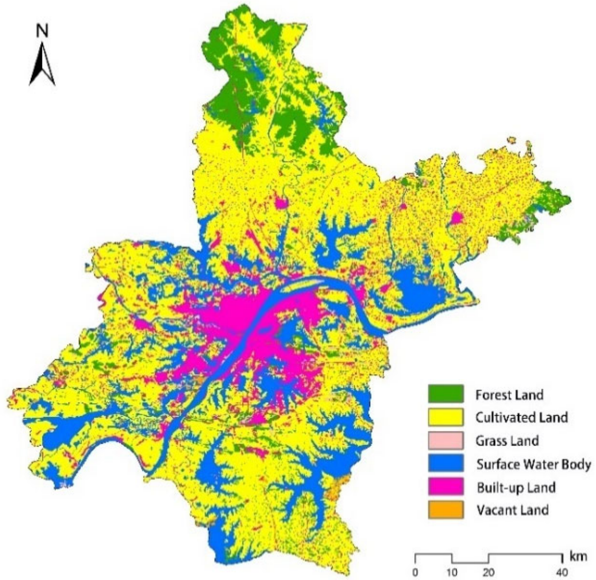
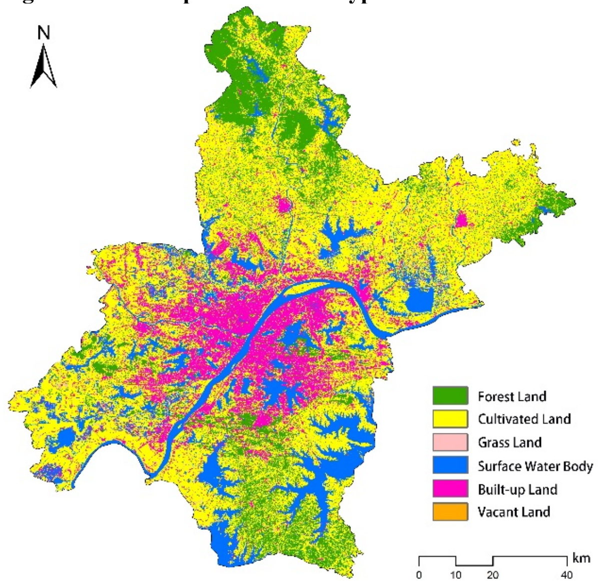


Figure 5: GIS Map of Land Use Types in Wuhan at 2018



4.2.4 Driving Force Analysis of Land Use Type Change in the Research Area

The driving force is the main biophysical and socio-economic factors that guide the land use type transformation (Assessment, 2005). The factors affecting the change of land use type can be divided into two aspects: natural driving factors and human driving factors (Assessment, 2005). Human driving factors include population, social economy, policy, technology and urbanization, etc., and the influencing process of the natural driving force is an indirect, long-term and natural succession process (Yongjun, 2005). For the study of short time scale, its effect is not significant, so it is rarely considered. The role of human driving force is a direct, short-term and self-conscious driving process with short-term realization, so it is often studied as the main driving force of land use change.

The impact of human driving factors on land use change can be studied from social and scientific aspects. Along with the social and economic development in different periods, the idea of people or the transition of the government policy to encourage people to change demand of the land services type and amount, lead to changes in land use, also can become a technical change (Dejun, 2004).

The 21st century is an important period for China to transform from a planned economy to a market economy. The comprehensive development of social economy has laid a certain material foundation for the establishment of urbanization. The relatively loose policy environment has promoted the development of China's real estate industry, and a large amount of cultivated land has been converted into built-up area, resulting in a large loss of cultivated land. At the same time, due to the huge pressure of population growth and the intensification of various social and economic activities, the development of planting industry and the expansion of agriculture inevitably lead to the continuous decrease of forest land. Another reason for the decrease in forest land is excessive logging and deforestation. If the forests are to be cut down which are in the area of returning cultivated land to forests, they must undergo a rigorous assessment before the government will issue a license (forest harvesting license) for logging trees. The license will limit the cutting location, area, species and methods, and after cutting, the license will require the logger to reseed the trees within a certain period. The forest harvesting license system is implemented to strictly control the annual amount of harvesting forest to protect forest land (Returning cultivated land to Forests Regulations, 2002). The decrease in grass land is the result of natural conditions and social-economic environment. With the rapid development of economy, the urban scale is expanding, and the demand for built-up area is also increasing. In a word, policy regulation and economic drive are the main reasons for land use type change in Wuhan.

4.3 Urban Ecosystem Services Changes in the Research Area

4.3.1 Total UESV Changes in the Research Area

According to the collected data of each land use type changes (Table 7), Table 6 and formula (5), the change extent of each land type is calculated. The calculation results are shown in Table 12 and Chart 10 below.

It can be seen from Table 12 and Chart 10 that the total amount of UESV in 2008,2013 and 2018 was 110.936 million yuan, 110.082 million yuan and 99.052 million yuan, showing an overall decreasing trend. During the 10-year period, the first five years decreased by 0.854 million yuan and the following five years by 11.03 million yuan. The total value of the reduction was 11.884 million yuan. It shows that the change of land use type in the first five years has less impact on the reduction of UESV in Wuhan, but in the next five years, with the acceleration of the construction speed of Wuhan city, the demand for built-up area increased greatly, encroaching on the area of the original cultivated land and surface water body. This indicates that the economy developed rapidly from 2013 to 2018, and the change of land use type was developing towards the trend of reducing UESV.

From the perspective of land use type, surface water body accounts for the largest proportion of UESV in Wuhan, followed by cultivated land and forest land. The UESV provided by the surface water body decreased the most, with the loss of UESV of 12.522 million yuan. Although the overall area of the surface water body is limited, its ESV coefficient per unit area is the highest, so it has a huge impact on UESV. During this period, although the government introduced a series of measures, few measures related to surface water body were taken. The results also indicate that the policy measures implemented in land use type change failed to effectively improve UESV.

Secondly, the built-up area and cultivated land were reduced by 5.069 million yuan and 4.489 million yuan. However, the built-up area provided by the negative UESV, indicating that the built-up area in the decade actually increased, but also because of the increase in built-up area, exacerbated the overall UESV in Wuhan reduction. Although the total area of cultivated land accounts for a large proportion, its UES value coefficient has little impact on the total value, ranking the second from the last, so its total value of UESV is at the third rank.

During the ten years, the least loss of UESV was the vacant land, which only lost 0.024 million yuan. The change in land use types of forest land and grass land provided positive growth for UESV, which increased by 10.2 million yuan and 0.019 million yuan respectively. Forest lands contributed the most UESV growth during this decade, benefits from the implementation of a series of government policies during this decade and the increasing awareness of the importance of forests. Wuhan has noticed the demand for UES in the process of urban development, the implementation of a series of policies, such as "return to the forest" to ensure the sustainable development of UES.

From the perspective of change rete, Wuhan's total UESV decreased by 10.713% over the ten years, and the change rate in the second five years was 10.02%, far higher than the change rate of 0.77% in the previous five years. It shows that the change in land use type in the second five years has a much higher negative impact on UESV than in the previous five years. This is inseparable from the rapid development of Wuhan and the development model of sacrificed ecological environment during the period 2013-2018.

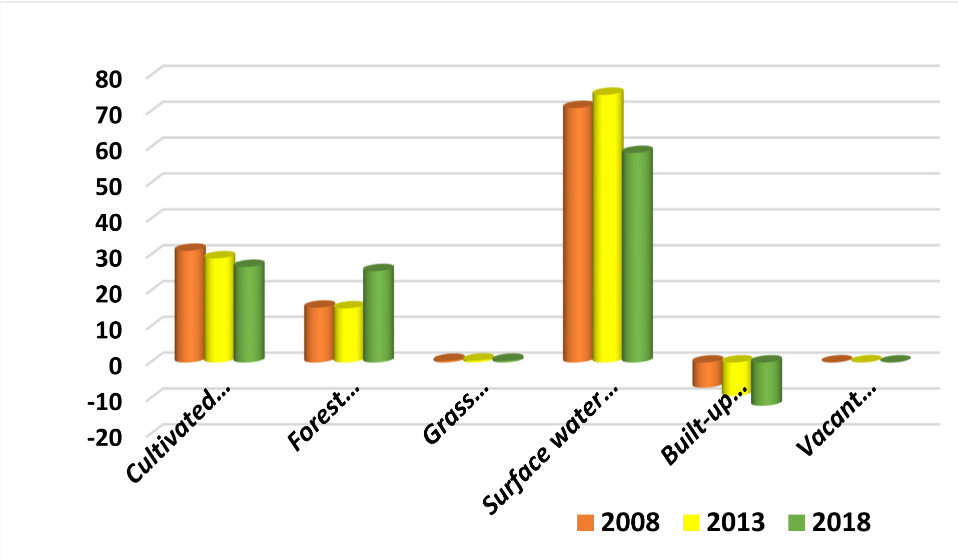
The biggest change in the decade was the built-up area, which is consistent with the rapid development of Wuhan in the decade, with a 72.185% increase in the built-up area. Unlike others, it had a negative impact on UESV in Wuhan.

This was followed by forest land, which increased by 66.566%, which is closely related to the policies issued by the Wuhan government and the increase in people's awareness of the value of forest ecosystems. Surface water body ecosystems and cultivated land ecosystems decreased by 17.645% and 14.387%. The waters increased slightly by 5.202% in 2008-2013 but declined sharply over the next five years. It shows that the land development plan of Wuhan 2013-2018 sacrificed a large amount of surface water body to achieve the purpose of increasing built-up area, which led to a sharp decrease in the contribution of the surface water body ecosystem to UESV. Cultivated land has been declining steadily during this decade, and its contribution to UESV has shifted to forest land ecosystems.

Table 12: Total UESV Changes in Wuhan within 2008-2013-2018

Land Use Types		Cultivated land	Forest land	Grass land	Surface water body	Built-up area	Vacant land	Total
UESV (Million RMB)	2008	31.202	15.324	0.442	70.965	-7.023	0.027	110.936
	2013	29.111	15.113	0.505	74.656	-9.327	0.024	110.082
	2018	26.713	25.524	0.461	58.443	-12.092	0.004	99.052
2008-2013	Change Value (Million RMB)	-2.090	-0.211	0.063	3.691	-2.304	-0.003	-0.854
	Change Rate (%)	-6.699	-1.375	14.282	5.202	32.814	-10.958	-0.770
2013-2018	Change Value (Million RMB)	-2.399	10.411	-0.044	-16.213	-2.765	-0.021	-11.030
	Change Rate (%)	-8.240	68.888	-8.722	-21.717	29.644	-85.174	-10.020
2008-2018	Change Value (Million RMB)	-4.489	10.200	0.019	-12.522	-5.069	-0.024	-11.884
	Change Rate (%)	-14.387	66.566	4.314	-17.645	-72.185	-86.799	-10.713

Chart 11: 2008-2013-2018 Wuhan UESV change trend of each land use types



4.3.2 Changes of a single function in UESV in the Research Area

According to the collected data of each land use type changes (Table 7), Table 6 and formula (6), the change extent of each land type is calculated. The calculation results are shown in Table 13 and Chart 11 below.

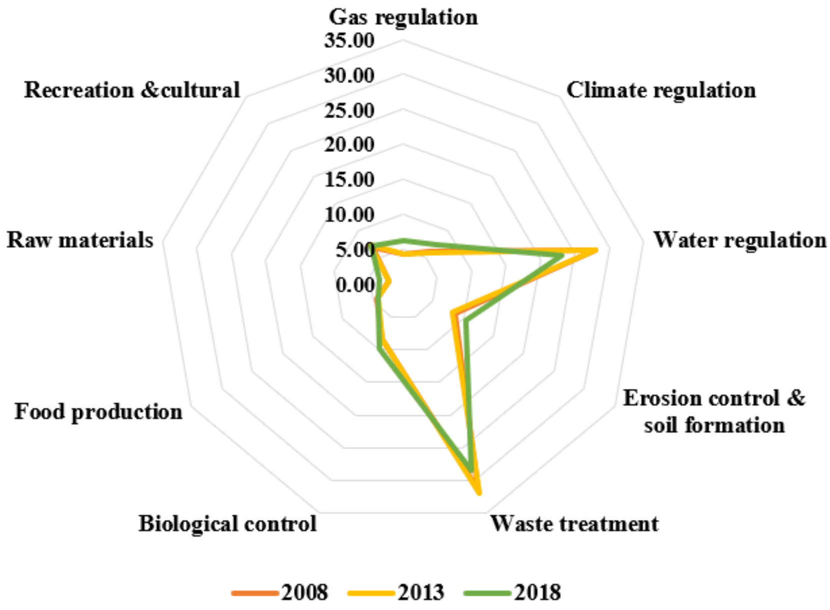
Table 13: 2008-2013-2018 Changes of a single function in UESV in Wuhan (Million RMB·a^{-1})

Service Items	2008		2013		2018		UESV Changes		
	UESV	(%)	UESV	(%)	UESV	(%)	2008-2013	2013-2018	2008-2018
Gas regulation	4.76	4.29	4.58	4.16	6.07	6.13	-0.18	1.49	1.31
Climate regulation	6.68	6.02	6.43	5.84	7.24	7.31	-0.25	0.81	0.56
Water regulation	31.17	28.10	30.86	28.03	22.90	23.12	-0.31	-7.96	-8.27
Erosion control & soil formation	9.46	8.53	9.00	8.18	10.33	10.43	-0.46	1.34	0.87
Waste treatment	34.74	31.32	35.14	31.92	28.10	28.37	0.40	-7.04	-6.65
Biological control	9.42	8.49	9.38	8.53	9.79	9.88	-0.04	0.41	0.37
Food production	4.76	4.29	4.47	4.06	4.13	4.17	-0.29	-0.34	-0.63
Raw materials	2.29	2.07	2.24	2.03	3.44	3.47	-0.05	1.20	1.15
Recreation &cultural	7.65	6.89	7.98	7.25	7.05	7.12	0.33	-0.92	-0.59
Total	110.93	100	110.07	100	99.04	100	-0.85	-11.03	-11.88

In terms of the total UESV of each single function factor, the waste treatment offered the largest UESV among all service function, accounting for 34.74 Million RMB in 2008, 35.14 Million RMB in 2013 and 28.10 Million RMB in 2018, accounting for 31.31%, 31.92% and 28.37%. Next is water regulation. The functional value of the three time-nodes is 31.17 Million RMB, 30.86 Million RMB and 22.90 Million RMB, accounting for 20.10%, 28.03% and 23.12%.

From the perspective of the overall trend of the UESV change of individual service functions, the value of all service items showed a decreasing trend during the decade 2008-2018. Water regulation and Raw materials are both decreasing in two periods. Water regulation and Waste treatment declined significantly during this decade, and Water regulation decreased slightly from 2008 to 2013, but sharply from 2013 to 2018, with a decrease of 7.96 Million RMB. Waste treatment showed a small increase trend from 2008 to 2013, with an increase of 0.4 Million RMB, but a sharp decrease from 2013 to 2018, with a decrease of 7.04 Million RMB. Recreation & culture increased by 0.33 Million RMB in the first five years, but the reduction value in 2013-2018 is greater than that in the previous five years, and the overall decrease in ten years is 0.59 Million RMB. Gas regulation, Climate regulation, Erosion control & soil formation, Biological control and Raw materials decreased in the first 5 years, but the increase in the latter 5 years was higher than the decrease before. Therefore, from the perspective of 10 years, the overall situation is rising.

Chart 12: 2008-2013-2018 Single Function of UESV changes the trend of each land use types in Wuhan



From the radar chart, the value change of most service functions is stable, and the relatively large changes are Gas regulation, Water regulation and Erosion control & soil formation. Food production and Biological control remain basically unchanged. These changes are only a comparison between 2008 and 2018, and there is little change compared to 2008 and 2013. It shows that the change of land use type during 2013-2018 has a greater impact on UESV than the previous 5 years.

4.3.3 Sensitivity Analysis of UESV in the Research Area

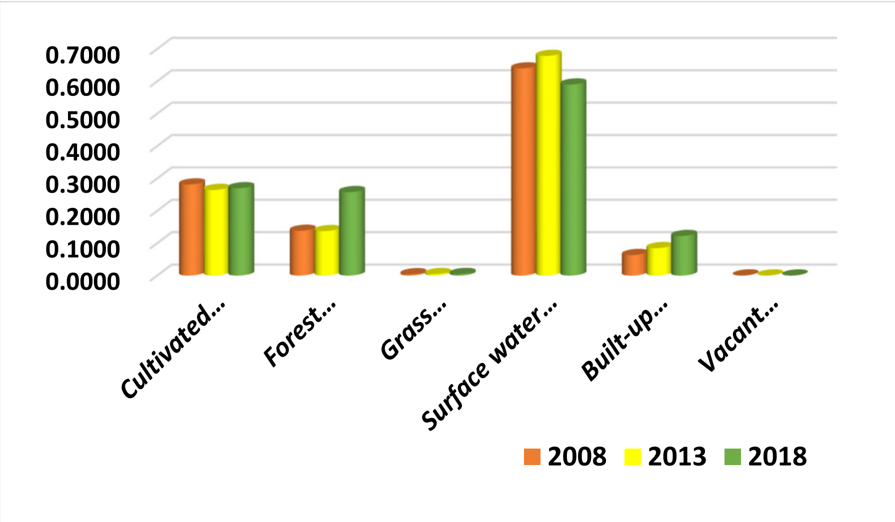
According to the calculation method of sensitivity analysis in 3.6.2.2, the UES value coefficient of cultivated land, forest land, grass land, surface water body, built-up area and vacant land is adjusted up and down by 50% respectively, and the adjusted UES value coefficient is applied to estimate the total UESV of Wuhan in 2008, 2013 and 2018. The results are shown in Table 14 and Chart 12.

The results in Table 14 show that, in all cases, CS of the value coefficient is less than 1. The minimum value is 0.00036, that is, when the UES value coefficient of vacant land increases by 1%, the total UESV will increase by 0.00036%. The maximum value is 0.6782, that is, when the UES value coefficient of surface water body increases by 1%, the total UESV will increase by 0.6782%. This indicated that total UESV is inelastic for UES's VC, and the above results indicate that the value coefficient selected in this thesis is suitable for Wuhan.

Table 14: Coefficient of Sensitivity and Changes of Total UESV in Wuhan After Adjusting Value Coefficient

Land Use Types	VC After Adjusting	UESV (Million RMB) 2008	UESV (Million RMB) 2013	UESV (Million RMB) 2018	Coefficient of Sensitivity 2008	Coefficient of Sensitivity 2013	Coefficient of Sensitivity 2018
Cultivated land VC+50%	91.715	126.537	124.638	112.408	0.2813	0.2645	0.2697
Cultivated land VC-50%	30.572	95.335	95.527	85.695			
Forest land VC+50%	290.010	118.598	117.639	111.814	0.1381	0.1373	0.2577
Forest land VC-50%	96.670	103.274	102.526	86.290			
Grass land VC+50%	97.598	111.157	110.335	99.282	0.0040	0.0046	0.0047
Grass land VC-50%	32.533	110.715	109.830	98.821			
Surface water body VC+50%	610.146	146.419	147.410	128.273	0.6397	0.6782	0.5900
Surface water body VC-50%	203.382	75.454	72.754	69.830			
Built-up area VC+50%	-132.782	107.425	105.419	93.006	0.0633	0.0847	0.1221
Built-up area VC-50%	-44.261	114.448	114.746	105.098			
Vacant landVC+50%	5.571	110.95	110.094	99.054	0.0002	0.0002	0.000036
Vacant land VC-50%	1.857	110.923	110.070	99.050			

Chart 13: Changes in CS of UESV from 2008 to 2018



According to Chart 12 and Table 14, the CS of the built-up area increases gradually at three different time nodes, which is 0.0633 in 2008, 0.0847 in 2013 and 0.1221 in 2018. This suggests that the changes of UES value coefficient of built-up area during this decade have an amplification impact on the total value. The sensitivity coefficient of cultivated land and surface water body showed a decreasing trend, indicating that their influence on UESV was gradually decreasing. CS of grass land and vacant land are small, indicating that the change of VC has little impact on the change of UESV in Wuhan.

4.4 Evaluation of the impact of LUCC on UESV Changes

4.4.1 Analysis of Grey Relevant between Land use types and UESV in Wuhan

Using the data of Table 15, with the calculation method of grey relevant analysis (formula (8) and (9)) by Data Processing System software, the relevant degree of UESV to Wuhan total for each land use type is obtained, see in Table 16.

Table 15: Raw data on UESV of Each Land Use Types in Wuhan 2008-2018 (Million RMB)

	2008	2013	2018
X_0	110.936	110.082	99.052
X_1	31.202	29.111	26.713
X_2	15.324	15.113	25.524
X_3	0.442	0.505	0.461
X_4	70.965	74.656	58.443
X_5	-7.023	-9.327	-12.092
X_6	0.027	0.024	0.004

X0——Total urban ecosystem services value;
X1——Urban ecosystem services value of cultivated land;
X2——Urban ecosystem services value of forest land;
X3——Urban ecosystem services value of grass land;
X4——Urban ecosystem services value of surface water body;
X5——Urban ecosystem services value of built-up area;
X6——Urban ecosystem services value of vacant land;

Table 16: Grey Relevant Degree and Relevant Sequence between Total UESV and the UESV of Each Land Use Types

	2008-2013		2013-2018	
	Relevant Degree	Relevant Sequence	Relevant Degree	Relevant Sequence
X_{01}	0.6504	1	0.6159	1
X_{02}	0.5305	3	0.3846	4
X_{03}	0.3376	5	0.3479	5
X_{04}	0.6057	2	0.5066	2
X_{05}	0.4875	4	0.4731	3
X_{06}	0.3027	6	0.3044	6

X_{01}——Relevant degree of cultivated land UESV on the total UESV in Wuhan;
X_{02}——Relevant degree of forest land UESV on the total UESV in Wuhan;
X_{03}——Relevant degree of grass land UESV on the total UESV in Wuhan;
X_{04}——Relevant degree of surface water body UESV on the total UESV in Wuhan;
X_{05}——Relevant degree of built-up area UESV on the total UESV in Wuhan;
X_{06}——Relevant degree of vacant land UESV on the total UESV in Wuhan;

As can be seen from Table 16, the relevant sequence of each land use types' UESV for the total UESV in Wuhan is as:

2008-2013 Cultivated land > Surface water body > Forest land >Built-up area > Grass land > Vacant land;

2013-2018 Cultivated land > Surface water body > Built-up area > Forest land > Grass land > Vacant land.

This indicates that UESV of cultivated land and surface water body has the largest influence on the total amount, which is mainly because, among all land use types, cultivated land occupies the largest proportion of total area in this period. Although the area of surface water body is not the largest, its UES value coefficient per unit area is the highest, reaching 406.764 RMB/km^2 ·a. Although the area of the surface water body has decreased from 2013 to 2018, the extent is not large (see in Figure 5), which does not affect his contribution to the total amount of UESV in Wuhan. The built-up area ranks 4th in the first 5 years and 3rd in the second 5 years. Although its relevant degree is not greatest, it must be recognized that the increase in built-up area will hinder the function and value of ecosystem services because the impact of built-up area on UESV is negative. From the change of the area of built-up area (Figure 6), the growth rate continued to rise during 2008-2018, and the growth rate slowed down in the next five years, mainly because the effect of government regulation measures. The relevant degree of UESV of vacant land to the total UESV is the lowest, mainly because the vacant land area and the UES value coefficient of unit area are relatively small.

Chapter 5: Conclusions and recommendations

5.1 Introduction

The land itself is an important natural resource and a basic ecological environment element, rational land use is the basis, key and guarantee of ecological environment construction (Foley, Defries, et al., 2005). Wuhan is now facing a severe land use situation (Wukang, M. and Xiaoqing, C., 2018). It is necessary to ensure the land demand for social and economic development, and also to take into account environmental protection and ecological construction. This requires scientific analysis of the impact of land use on the urban ecosystem services with the basis of intensive study of land ecological environment issues. Summarize and promote land use management that is beneficial to the urban ecological environment, make the protection and construction of urban ecological environment on a big scale, and propose reasonable planning for land use suitable for urban ecosystem services.

Land use and land cover change is the core area of global environmental change research. The process of land use and land cover change plays a decisive role in maintaining ecosystem services, and land-use change will inevitably affect UES's structure and function. Urban ecosystem services and land use and land cover change are essentially a pair of contradictory unity and restricting each other. Urban ecosystem services are the material basis for human survival and development, and the key of natural capital possessed by human beings. The land use process plays a decisive role in maintaining urban ecosystem services function (Xudong, Liding, et al., 1999). Urban ecosystem services structure and functions are changed by land-use changes. The land is the carrier of all kinds of ecosystem, and the type of ecosystem can also be called as the type of land use. UES have different functions, because changes in land use structure cause changes in various land use types, areas and spatial positions, lead to changes in various ecosystem types, areas and spatial distribution. At the same time, land use change also changes the appearance of the natural landscape and affects the material circulation and energy distribution in the landscape (Xudong, Liding, et al., 1999). These impacts will also manifest from changes in urban ecosystem services value.

Thus, land use results affect the structure of urban ecosystem services value. Land use and land cover change is the cause of the change of urban ecosystem services value, and the change of urban ecosystem services value can, in turn, affect land use and land cover change, resulting in the formation of new structure of land use. Because the change of urban ecosystem services value is also related to the unit area value, the relationship between land use and land cover change and urban ecosystem services value is not simply linear, but very complex.

All kinds of environmental problems are becoming more and more prominent in the continuous development and utilization of land and form an interactive relationship with the way of land use. In particular, the problem of ecosystem caused by unreasonable land use mode not only restricts the development and utilization of land in turn, but also seriously affects the improvement of the quality of life of residents and the normal functions of cities, among which is the impact on urban ecosystem service (Bloom, Canning, et al., 2008). The main purpose of this thesis is to study how changes in land use types can have an influence on urban ecosystem services value. Changes in land use types will have a direct impact on the type and intensity of services provided by ecosystems. Only by introducing the value accounting of ecosystem services into the decision-making of land use can promote the rational development of natural resources and realize the sustainable use of land.

5.2 Discussion

5.2.1 Discussion of Sub-questions

Based on the analysis of the current situation of land use in Wuhan, this thesis systematically analyses the dynamic change model of land use type in Wuhan from different angles, such as the change extent, change speed, degree change and transfer matrix. On this basis, the change of ecosystem service value quantity caused by land use type change was analysed. The main findings are found in three aspects. In terms of land use change, the change of cultivated land is the largest, mainly transferred to forest land and built-up area. The change in surface water body causes the greatest change in value, followed by the built-up area. Finally, after analysing the impacts of land use and land cover change on urban ecosystem services, it is found that the two land areas whose changes have the greatest impact on value are cultivated land and surface water body. The results will answer the following questions:

Sub-question 1: What changes happened to the land use types of Wuhan during 2008-2018?

Through the analysis of the extent of land use changes in Wuhan, the results show that the change of cultivated land is the largest, which is reduced by 734.17 km^2 . The second reduction is in the surface water body, which is reduced by 307.84 km^2 . During this ten-years period, the number of ports in Wuhan has increased to 103 during this period (Overall plan for optimization and adjustment of port terminal resources in the core areas of Wuhan Yangtze River and Hanjiang River, 2018). For the economic development of the city, Wuhan has a unique advantage in the Yangtze River freight transport as a city where the two rivers meet. In addition to increasing the port on the Yangtze River Economic Belt during the period of 2013-2018, many landscape belts were established to ensure ecological balance. This reduces the area of the water and transforms it into the built-up area. The built-up area was the largest increase in all of the land use type during the 10-year period, with an increase of 572.68 km^2 . Followed by forest land, increased by 527.58 km^2 . This is related to the government's policy of "returning cultivated land to forests" (Jingtao, Ran, et al., 2004)and the policy of "China's new rural construction". The change range of grass land is the smallest of all types, and the overall trend is increasing, with a total increase of 2.93km^2. This is because in the rapid development of the city, grass land ecosystem is often ignored by people, and Wuhan's economic development is not dependent on animal husbandry, animal husbandry in Wuhan's GDP is only a small part (Wukang, M. and Xiaoqing, C., 2018). The overall change in vacant land is not significant.

Through the analysis of the dynamic degree of land use changes in Wuhan, the results show that the rate of change of built-up area during the ten-year period is the fastest in the positive growth, reaching 7.22%. This is closely related to the rapid economic and social development of Wuhan in this decade. The smallest change rate is grass land, the rate of change is 0.43%. The proportion of grass land in the land use type in Wuhan during this decade has been small, l, and it is often overlooked in the ecosystem. Local governments also have limited policies to protect grass land ecosystems, resulting in a small and slow change. Taking every five years as a time period, it is worth noting that the change rate of forest land shows a sharp positive growth during 2013-2018. This is also due to the government's policy of "returning cultivated land to forests" (Jingtao, Ran, et al., 2004). The rate of reduction of vacant land during the ten-year period was the fastest, reaching 8.68%, reflecting the sharp increase in land demand during the development of Wuhan. Especially in 2013-2018, the rate of change of vacant land was as high as 17.03%.

Through the analysis of the degree index of land use types in Wuhan, the results show that the degree of land use in Wuhan is relatively high and shows a trend of continuous growth. This indicated that Wuhan is a continuously developing city, which also confirms the reason for the increase of the built-up area.

Through the analysis of the transfer matrix of land use types in Wuhan, the results show that during the five years from 2008 to 2013, a large number of cultivated land and surface water body were lost, and the amount of built-up area increased sharply. 2.03% of the forest land, 7.62% of the grass land and 2.08% of the surface water body were turned to the built-up area. Vacant land is mainly transformed into cultivated land, surface water body and built-up area. The main transfer direction of cultivated land was the built-up area which was still the largest transfer direction. But the second large transfer direction is changed from the first five years of surface water body to the forest land during 2013-2018. This is closely related to a series of policies such as the "National forest belt protection and utilization plan (2010-2020)" implemented since 2010. The area of cultivated land, forest land, grass land and surface water body converted into the built-up area is less than the past five years. At the same time, more land was being converted from built-up area to cultivated land, forest land and grass land than in the previous five years. This is consistent with the development process in the region. Faced with serious environmental problems brought by economic growth, national and local governments have taken measures to restore the environment, protect natural resources and limit urban expansion.

Sub-question 2: To what extent has Wuhan's UESV changed during 2008-2018?

By calculating the changes in UESV in Wuhan during a decade, it can be seen that the overall number is decreasing. And the decrease in the second five years was greater than that in the first five years. From the perspective of land use types, the UESV provided by surface water body decreased the most, up to 125,220 yuan. Although the overall area of the surface water body is limited, its UES value coefficient per unit area is high, so it has a huge impact on UESV. It indicates that the measures taken by Wuhan government during this period to develop the port and transform the surface water body into landscape belt for the purpose of improving the ecological environment failed to improve UESV effectively. (Overall plan for optimization and adjustment of port terminal resources in the core areas of Wuhan Yangtze River and Hanjiang River, 2018).

From the perspective of changes of a single function in UESV in Wuhan, the waste treatment offered the largest UESV among all service function. From the perspective of the overall trend of the UESV change of individual service functions, the value of all service items showed a decreasing trend during the decade 2008-2018. Raw materials were decreasing in ten-years periods. Water regulation and Waste treatment declined significantly during this decade, and Water regulation decreased slightly from 2008 to 2013, but sharply from 2013 to 2018. Waste treatment showed a small increase trend from 2008 to 2013, but a sharp decrease from 2013 to 2018. Recreation & culture increased by 0.33 Million RMB in the first five years, but the reduction value in 2013-2018 is greater than that in the previous five years. Gas regulation, Climate regulation, Erosion control & soil formation, Biological control and Raw materials were rising during the ten years. Built-up area and cultivated land decreased by 50,069 yuan and 44,890 yuan. However, the negative UESV provided by the built-up area indicates that the built-up area actually increased during this decade. And it is precisely because of the increase of the built-up area that the overall UESV decrease in Wuhan is aggravated. Although the total area of cultivated land accounts for a large proportion, its UES value coefficient has little impact on the total value, ranking the second from the last, so its total value of UESV is at the third rank. The UESV brought by forest land and grass land ecosystem increased. The forest land increased by 66.566%, which was the second large change among all land use types (the first was built-up area, with negative growth).

Sub-Question 3： How does the change of LUCC in Wuhan explain the change of UESV in Wuhan during 2008-2018?

The change of land use pattern not only changes the structure of the ecosystem but also changes the service function of the ecosystem. Grey relevant analysis was carried out on them, and the analysis results were as follows:

2008-2013 Cultivated land > Surface water body > Forest land >Built-up area > Grass land > Vacant land;

2013-2018 Cultivated land > Surface water body > Built-up area > Forest land > Grass land > Vacant land.

The results show that the relevant degree of surface water body and cultivated land to urban ecosystem services is higher than other land use types, ranking the first and second, followed by forest land and built-up area. The relevant degree of vacant is minimal. indicates that the change in land use type of cultivated land has a great impact on the UESV of Wuhan. The impact of cultivated land is large because it accounts for the largest proportion of land use types in Wuhan, and the impact of surface water body is due to its UES value coefficient per unit area is the highest, reaching 406.764 RMB/km^2 ·a. Vacant land is small because both are the smallest of all land use types. By comparing the two time periods, it can be seen that the impact of built-up area changes on Wuhan's total UESV shows an upward trend, and its change is negatively correlated with UESV due to its UES value coefficient per unit area is negative (Su, Xiao, et al., 2012).

5.2.2 Discussion of Limitation

The evaluation of urban ecosystem services value in this thesis is based on the estimation of ecosystem value per unit. The amount of urban ecosystem services value, as a measure of the function of urban ecosystem services, is a way to quantify the economic, ecological, and social values in urban ecosystems to reflect the state of ecosystems. However, in the process of quantification, due to the imperfection of theoretical research and the different methods, there will be some differences between the evaluation results. Therefore, the theoretical basis and methods of urban ecosystem services value should be strengthened to make the calculation of UESV more systematic and standardized, and the results are more reliable.

The calculation of UESV in this thesis is based on the ecosystem calculation principle proposed by Costanza and Gaodi Xie et al., and their methods have been widely used after proposed. However, due to the adoption of the expert survey method for the formulation of the equivalent value coefficient table, there is a certain degree of subjectivity. In addition, due to the differences in the scale and location of research areas, the status and value of ecosystems in different regions are highly diverse. Therefore, when the equivalent value coefficient of Wuhan is used, it needs to be corrected in combination with the actual situation of Wuhan. Due to the limitations of the research, the availability of data and literature, this thesis only revised the equivalent value coefficient of the urban ecosystem service per unit area based on Ruijuan Duan's research, without referring to the ecosystem characteristics of Wuhan, and the research results inevitably have some deviations. In order to improve its objectivity, the relationship between urban ecosystem services value and its equivalent value coefficient should be further studied.

This thesis studies the impacts of land use type on urban ecosystem service value. However, the analysis method of land use and land cover change and ecosystem value quantity alone is not enough to fully solve the problem that urban ecosystem services are decreasing. Therefore, people's dynamic willingness to pay value for urban ecosystem services should be further considered comprehensively. On the other hand, due to the availability of data, not considering the impact of construction and maintenance demands on urban ecosystem services, it is inevitable that they are not comprehensive. Therefore, with the continuous improvement of measuring methods and the deeper understanding of people in concerning with urban ecosystem services， the assessment of the relationship between land use and land cover change and urban ecosystem services will be more accurate and complete.

5.3 Recommendations

When analysing the value of ecosystem services, this study found that the total value of ecosystem services in Wuhan is characterized by the significant proportion of cultivated land, surface water body and forest land. In the past ten years, there have been varying degrees of changes between various ecosystems in Wuhan, and there are many problems to be solved. In order to slow down the decline of the value of ecosystem services in Wuhan and make its ecosystem develop well, the following suggestions and countermeasures are put forward:

(a) Strengthen efforts to control land degradation and pollution. Wuhan is rich in land resources, but attention should be paid to planning and management in terms of utilization. In hilly areas, comprehensive land improvement should be vigorously promoted to actively prevent and control environmental degradation caused by soil erosion and geological disasters. Development should be according to local conditions, vegetation coverage should be strengthened appropriately, and the policy of returning farmland to forests should be continued to maintain good restoration capacity of the ecosystem. Reasonable allocation of land resources to ensure the balanced development of the ecosystem, so Wuhan should formulate corresponding legal policies to standardize the use of natural resources, strictly control the unreasonable built-up area. Policies should ensure that the area of surface water body, cultivated land, grass land and forest land ecological system. Because the change of land use directly affects the urban ecosystem service value in Wuhan. Therefore, the Wuhan government should carry out macro-control policies to ensure that the ecological system can provide the maximum value to urban and human beings.

(b) Focus on ecological land protection. The northern part of Wuhan is an ecological land zone. The ecological conditions of this region are good (as shown in Figure 3-5). Some agricultural land can provide spare land for the development of suburban agriculture. In addition, this study shows that the area of surface water body, forest land and cultivated land ecosystem in 6 kinds of ecosystems in Wuhan decreases greatly. Their influence on the urban ecosystem service value is larger, so the management department should strengthen the protection of surface water body and the cultivated land ecosystem. The establishment of wetland park and ecological forest will not only increase the area of water and ecological forest, but also improve the value of ecosystem services, and provide places for human sightseeing and entertainment. It is of great significance to protect the value of ecosystem services in Wuhan and avoid the deterioration of ecological environment caused by human factors.

(c) Enhance the protection of cultivated land to improve the value of agricultural products. The results in the analysis of grey relevant indicate that the changes in cultivated land within two five-year periods have the greatest influence on urban ecosystem services value. Therefore, it is necessary to protect cultivated land and improve the benefit of cultivated land users. Increased farmers' income, farmers increased the reclamation of vacant land or other land types, cultivated land increased, forming a virtuous circle. Here are some suggestions: firstly, to improve the management system of rural land contracting and management rights, to explore the establishment of a standardized system for the transfer of land contracting and management rights. Secondly, to vigorously develop the superior seedling industry and high value-added agricultural products processing industry, and to increase support for agricultural industrial enterprises, expand agricultural sales channels through e-commerce. Finally, to promote the development of Wuhan's characteristic agriculture and ecological leisure agriculture. Taking the road of combining ecological agriculture with sightseeing agriculture, highly valued the characteristics of sightseeing agriculture, building Wuhan agricultural production base and leisure agricultural sightseeing park, and continuously increasing farmers' income.

(d) Strengthen the protection of surface water body and establish a long-term mechanism for surface water body protection. In the analysis results of this thesis, the influence of surface water body on UESV is the second place. However, during the period from 2008 to 2018, surface water body is decreasing due to the establishment of ports. Therefore, the protection and construction of surface water body are imperative. Here are some suggestions: Firstly, to strengthen the publicity of surface water body protection and management in various forms, to carry out popular science activities to promote the importance of surface water body protection, to enhance citizens' awareness of the nature of surface water body protection. To form a good atmosphere in the whole society that cares about the surface water body attaches importance to and protects the surface water body. Secondly, to formulate surface water body protection regulations as soon as possible to provide legal support for protection and management. Finally, Increase the protection and construction of the surface water body, and incorporate the protection into the Wuhan economic and social development plan. Gradually establish a long-term management mechanism for surface water body protection.

5.4 Conclusions

Based on GIS and DPS software, thesis analyzes the land use type change characteristics of Wuhan from 2008 to 2018 by using dynamic model and transfer matrix method.On this basis, with reference to the unit area value of urban ecosystem services in China and combined with the analysis of coefficient of sensitivity of ecosystem services, the change characteristics of the value from 2008 to 2013 to 2013 are analyzed.

The research results have important practical implications for the management of urban land use growth and the continued growth of urban ecosystem services value. The main conclusions are as follows:

(a) During the period of 2008-2018, with the rapid advancement of urbanization, the land use type in Wuhan changed significantly, and the area of the built-up area increased continuously, with an increase of 572.68km^2 and an average annual growth rate of 7.22%. The areas of Cultivated land and surface water body showed a decreasing trend, and the decreasing amount are 734.17km² and 307.84km². 41.24% of the reduced area was replaced by built-up area, and cultivated land became the main source of built-up area.

(b) According to the two groups of relevant sequences obtained: 2008-2013 Cultivated land > Surface water body > Forest land >Built-up area > Grass land > Vacant land; 2013-2018 Cultivated land > Surface water body > Built-up area > Forest land > Grass land > Vacant land. It is expected that there will be three different development scenarios for changes in land use types and urban ecosystem services values in Wuhan, where the difference in urban ecosystem services values is significant. Among them, Scenario Ⅰ (increased according to existing development trends) > Scenario Ⅱ (Cultivated land moderate protection) > ScenarioⅢ (integrating ecosystem GDP and planning eco-cities). Here are comparing the values of urban ecosystem services.

(c) The calculation results of urban ecosystem services value show that the total value of urban ecosystem services in Wuhan has been decreasing continuously in the past 10 years, from 110.936 million RMB in 2008 to 99.052 million RMB in 2018. Cultivated land and surface water body change have the greatest impacts on the change of total service value.

Since Wuhan is the provincial capital of Hubei Province and located in the Yangtze River and Hanjiang Rivers, the value of its exploitability is higher than that of the inland areas. The population density of cities has increased year by year and the economy has developed rapidly. With the participation of human factors, the construction of the Yangtze River Basin has gradually increased. The waters of the original Yangtze River Basin have been embezzlement, and the original topography and landform have been changed, and the function of urban ecosystem services of Wuhan have been reduced.

In addition, due to the participation of human activities, the original natural length of the Yangtze river coastline is changed, making it reduce year by year. Moreover, many natural landscapes have been transformed into man-made landscapes, such as the cultivation activities along the river and the construction of ports, which will reduce the original bedrock bank lines and gravel shoreline, and gradually increase the cultivations areas and ports, thus reducing the value of natural landscapes in terms of aesthetics (Wandong, Chuanqing, et al., 2014). Due to the lack of reasonable utilization and protection of resources by human beings, the ecosystem problems gradually become serious, and the service value will decrease accordingly. Therefore, in the process of economic development and social construction, it is necessary to coordinate the relationship between various ecosystems and land, ensure the healthy development of the ecosystem, and reduce the threats to the ecosystem caused by various human activities, to achieve sustainable development.

The research results of this thesis provide references for the urban ecosystem development planning of Wuhan and the cities with similar ecosystem conditions, such as Shanghai and Liuzhou. At present, Wuhan is still in the stage of rapid urbanization development, facing the large-scale development with urban ecosystem resources. At this moment, it is urgent to strengthen the dynamic monitoring of regional ecosystem, pay attention to the development of ecological industry, urbanization process, ecosystem degradation and other phenomena, and comprehensive governance to achieve the harmonious development of urban ecosystem services and social economy.

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Annex 1: Data processing system (Software)

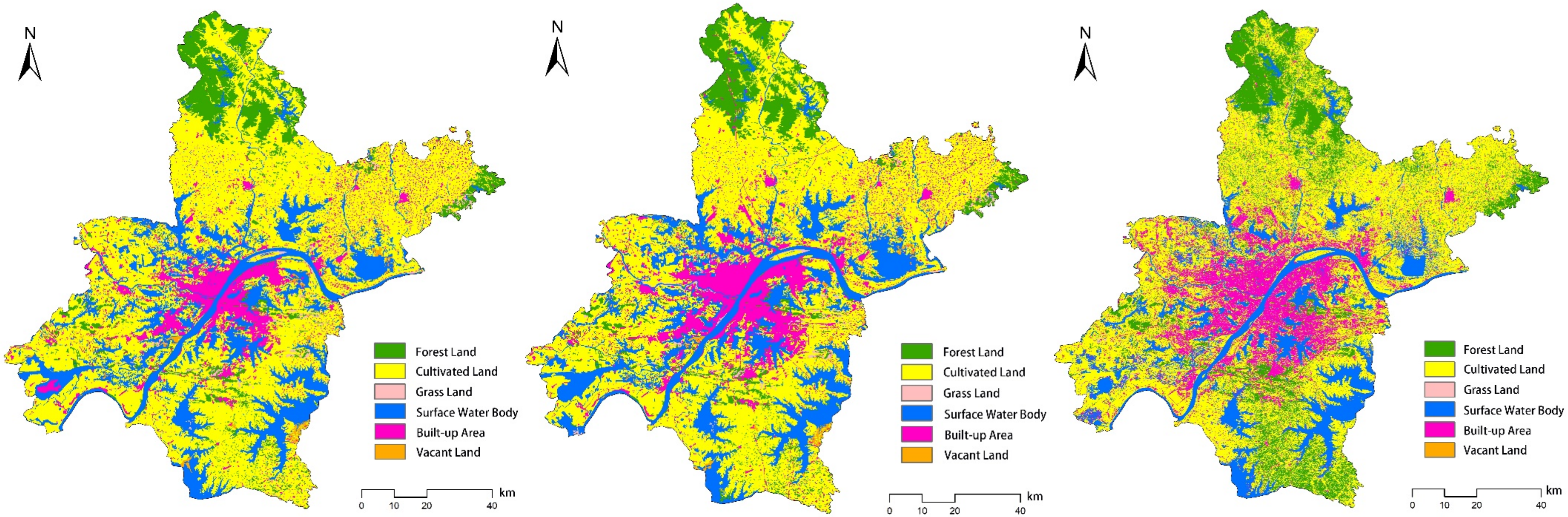
Relevant sequence of total UESV (2008-2018) and other factors

MAX T-L Δmax = 0.3477		
Relevant sequence of total UESV (2008-2013) and other factors		
No.	Factors	Relevant degree
X_{01}	cultivated land	0.6504
X_{02}	forest land	0.5305
X_{03}	grass land	0.3376
X_{04}	surface water body	0.6057
X_{05}	built-up area	0.4875
X_{06}	vacant land	0.3027

MAX T-L Δmax = 0.3115		
Relevant sequence of total UESV (2013-2018) and other factors		
No.	Factors	Relevant degree
X_{01}	cultivated land	0.6159
X_{02}	forest land	0.3846
X_{03}	grass land	0.3479
X_{04}	surface water body	0.5066
X_{05}	built-up area	0.4731
X_{06}	vacant land	0.3044

Annex 2: Research Instruments

GIS Map provided to Wuhan land use types layout at 2008-2013-2018



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