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Evaluation and Dynamic Mechanism of Ecological Space in a Densely Urbanized Region During a Rapidly Growing Period—A Case Study of the Wu-E-Huang-Huang Metropolitan Interlocking Region

Zhiyong Wang, Tixing Yang, Helin Liu *, Man Yuan, Ji Luo and Chun Li

School of Architecture and Urban Planning, Huazhong University of Science and Technology, Hubei Engineering and Technology Research Center of Urbanization, Wuhan 430074, China; wangzhiyong@hust.edu.cn (Z.W.); yangtixing@hust.edu.cn (T.Y.); yuanman_aup@hust.edu.cn (M.Y.); luoji@hust.edu.cn (J.L.); lichun@hust.edu.cn (C.L.)

* Correspondence: hl362@hust.edu.cn

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Abstract: Ecological space in a densely urbanized region plays a very important role in its development. Therefore, a scientific evaluation of ecological spaces in a densely urbanized region is the main prerequisite for corresponding ecological space planning. Taking the Wu-E-Huang-Huang Metropolitan Interlocking Region as the study area, the paper selects six types of ecological factors, including the location index, land status, terrain conditions (elevation, slope), hydrological conditions (rivers, lakes), landscape value, and road traffic. By using a single factor evaluation and a multi-factor comprehensive evaluation method involving GIS, the paper presents an evaluation of the ecological space conditions of the Wu-E-Huang-Huang Metropolitan Interlocking Region. In line with the result, the ecological environment of the region is divided into four levels: highly sensitive areas, sensitive areas, weakly sensitive areas and insensitive areas. On this basis, the underlying problems and mechanisms are explored further.

Keywords: evaluation; dynamic mechanism; ecological space; densely urbanized region

1. Introduction

In the process of new urbanization in China, gigantic densely urbanized regions have been formed due to the rapid development of cities and regions. In the China Major Function-Oriented Zone Plan 20 main urban agglomerations have been listed as the key regions for development. These agglomerations cover about 25% of China's total territory and have led to 62% of China's population producing 80% of China's national economic growth. According to Northam's S curve of urbanization, Chinese urbanization will continuously and increasingly develop for a very long period, which is evidenced by the rapidly increasing urbanized population, megalopolises, and urban agglomerations. However, alongside the rapid urbanization of these regions is the pressing and challenging fragmentation of ecological space. Due to the swarming of people from the countryside into densely urbanized regions, the population and construction in these areas have been expanding quickly, which has been threatening the safety of urban ecological spaces.

The emergence and popularity of theoretical study on urban and regional ecological spaces was catalyzed by residents' awareness of ecological and environmental threats which are largely caused by rapid and unsustainable urbanization. To counter these threats, a series of initiatives have been carried out. The representative humanism models utilized were Y. Mata's Linear City, Howard's Garden

City, and Saarinen's Organic Decentralization. The main practical example of this is London, whose spatial expansion was controlled by a green belt in the Great London Plan in 1944. This approach was later used in the green belt planning of cities such as Tokyo, Moscow, Paris, and Copenhagen [1]. Nevertheless, a "Return to Nature" was proposed for urban development when human beings were exposed to environmental risks in the 1950s, which led to diversified and ecological urban structure plans and increased study of the concept of the ecological city. The basic ideas were to build ecological infrastructure, regional green land, an ecological corridor, an ecological network, and an environmental corridor. Consequently, the "ecological reform" movement in city studies was developed. Meanwhile, similar concepts were also proposed by Chinese scholars. For example, Yu Kongjian promoted a "negative-planning" model [2]. Additionally, during the early 21st century, ecological thoughts began to fundamentally direct the way that people sought to solve all lifestyle-related problems. This has led to a major shift in attention towards nature-integrated urban and regional structure studies on the basis of "ecological orientation". This idea was first summarized by an American scholar named Honachefsky, in order to deal with problems posed by an endless and disordered expansion of American cities [3]. This orientation shift quickly obtained global resonance and turned the simple "protection" model underpinned by "ecological optimization" into a model of "ecological orientation", which integrates ecology with regional development [4].

Per Bolunda and Sven Hunhammar were the pioneers of a study approach focusing on the benefits of the integration of ecological space with city and regional development [5]. By analyzing the local eco-system service, they concluded that local eco-system services have a significant impact on quality of life and development quality in urban areas. Although cities have become the dominant human settlement pattern, cities themselves only constitute a small part of the total ecological space appropriated by their human inhabitants [6]. Although in most cases an eco-system's performance declines as urban density increases, there was considerable variation in the relationship between the two factors. This suggests that at any given density, there is substantial room for maximizing ecological performance.

In light of the potential for growth and public health, a series of studies emerged with the goal of evaluating the eco-value or the sensitivity of the ecological space in highly-urbanized regions. Generally, these studies came from two main approaches. One comes from the theories developed by Landscape Ecology, which emphasizes the landscape's value and its connection with the lives of its inhabitants and its ecological security [7]. Accordingly, a series of methods have been applied, such as structural equation modeling (SEM), contingent valuation, social value spectrum, and picture-based decoding [8,9]. The other approach comes from Urban Morphology theories, relies on remote sensing, and focuses on land cover change [10]. The second approach includes GIS (Geographical Information System) overlapping analysis, network analysis, scenario analysis, etc. [11,12]. In particular, in the planning domain, there are specific topics that are related to the ecological space. For instance, land suitability analysis [2] focuses on the coupling of land use and ecological capacity; the landscape ecological approach [13] deals with the composition of spatial forms; the ecological carrying capacity approach [14] tends to determine the maximum development level that a region or city can support; the circular economy model [15] aims to build an environmentally-friendly economy to restore and maintain the eco-system; and ecological regionalization [16] emphasizes the complex adaptive system of the region. In recent years, the emergence of big data analytics and geo-computation presents new ways to identify the ecological space and to evaluate its sensitivity. In addition, the initiative of "Smart City" has fundamentally enriched data related to the ecological space as new sensors and unmanned aerial vehicle (UAV) are being applied for sensing, monitoring and networking the natural and built environment [17,18].

In terms of the dynamic evolution mechanism of the ecological space in urbanized regions in China, most studies are on the coastal areas featured by high ecological sensitivity [19,20]. Yet, regions in middle China experiencing rapid urbanization have been overlooked for a long time despite the fact they deserve deep investigation. It is highly recognized that ecological sensitivity is fundamentally influenced by the complex interaction between forces from both natural and human activities [1]. It is

emphasized that human activities involves different interest parties in different socioeconomic contexts, particularly in different countries with different administrative structures.

As reviewed above, the idea of eco-orientation is deeply accepted by scholars as well as residents. There are also practices which integrate eco-values into urban and regional plans. Yet, in most cases, these issues are discussed qualitatively but not quantitatively, which lack persuasive accuracy and conviction. Therefore, this paper presents a case study of Wu-E-Huang-Huang, a highly urbanized region in Hubei province located in the middle part of China, to demonstrate the GIS-based approach, evaluation results and underlying mechanisms.

2. Study Area, Data and Methods

2.1. Study Area

The study area is Wu-E-Huang-Huang Metropolitan Interlocking Region. It is the core region of cities and towns in the eastern part of Hubei Province, middle China. Specifically, this interlocking region contains Wuhan metropolitan area, Ezhou central area, Huangshi central area, Daye central area, Huanggang central area, Sanhua group of Xishui County and Tuanfeng county, which are surrounded by lakes, forests and woods, etc. It stretches from the western outer ring of Wuhan (Jingzhu Highway) to the Daguang highway in the east, with (planned) Huangxian highway to the south and Wu Ying highway to the north (Figure 1).

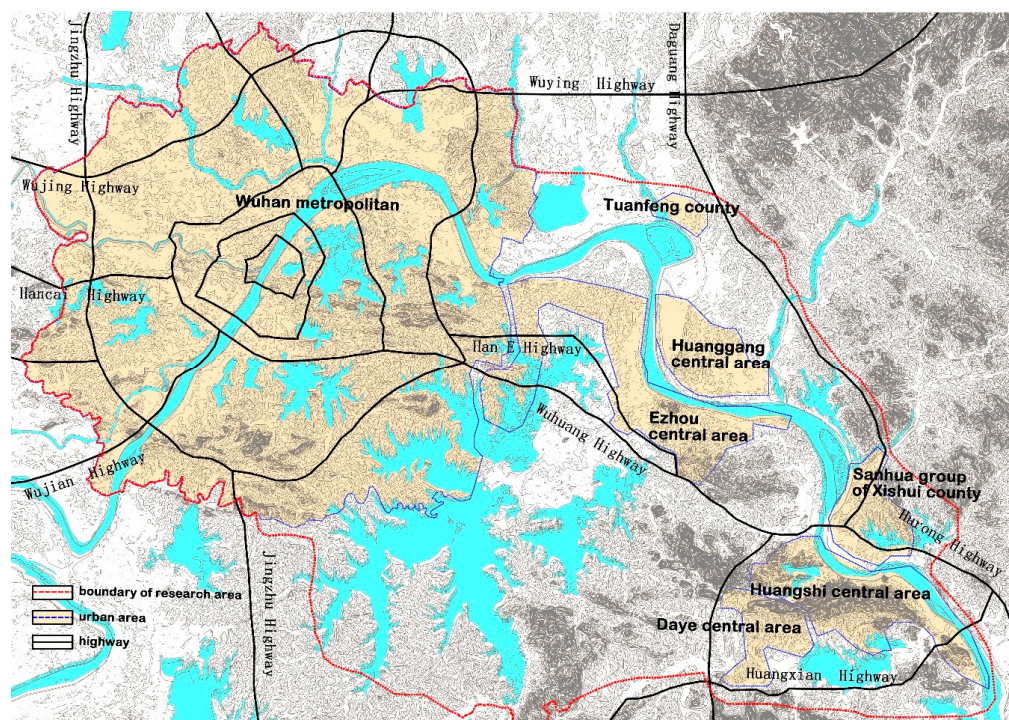


Figure 1. Location of Wu-E-Huang-Huang Metropolitan Interlocking Region. Source: the authors.

This region covers around 7470 km² and has a registered population of 11.3 million, and a residence population of 12.6 million in 2017. The residence population density reaches 1547 capita/km². With a generally flat terrain, this region has an elevation ranging from 20 m–50 m (against the Huanghai absolute evaluation base point) and decreases from the northeast to the southwest. The Yangtze River flows through this region which also contains dozens of smaller rivers and lakes. Most cities/towns in this area are undergoing rapid urbanization, showing a spatially-interlocking trend. So, it is significant to study the ecological space of this region so that the expansion of the cities and towns can be well regulated and the regional ecological system can be properly reserved (Figure 2).

In order to identify the most sensitive factors to this region, first we listed all the commonly used factors by scholars across the globe [21,22]. Then by looking into this region's terrain, landscape, ecological environment and its development goals, six impact indexes were considered. They are location index, land status, terrain condition (elevation, slope), hydrological condition (rivers, lakes), landscape value, and road traffic. The connotation of each index is explained in Table 1.

Table 1. The six indexes considered in the evaluation.

Impact Index	Main Connotation
Location Index	The ecological sensitivity of a certain physical factor may vary in different locations. For instance, for a river, the upstream of it is comparatively more sensitive compared with that in the downstream.
Land Status	Land status is mainly defined by the land-use type. The underlying reason is that different land-use may have different sensitivity to the same development activity. In this research, there are three land-use types: natural ecological space, farming and grazing space, and urban development space.
Terrain Condition (Elevation and Slope)	Terrain condition is mainly composed by elevation, slope, slope aspect and so forth, majorly affecting the ecological environment and landscape quality.
Hydrological Condition	As an indispensable part of the ecological system, water is surrounded by high value of biodiversity. Moreover, rivers and lakes are necessary to the existence and development of a city because most densely-urbanized regions are beside water. The paper considers water distribution and water buffering. The impact degree is three grades: highly important, important and ordinary.
Landscape Value	Natural landscape and cultural landscape are the two major kinds of landscapes in the ecological space of the densely urbanized region. "Landscape value is composed by natural object, cultural heritage, aesthetic feeling, social values and so forth" [23]. Therefore, this paper considers landscape value from four perspectives: appreciation value, historical and cultural value, vision environment, popularity and influence.
Road Traffic	Road traffic is another impact factor for the ecological environment which is particularly influenced by transportation facilities such as highway and railway. By considering road construction, possibility of blockage of animal migration, exhaust emission and noise, the paper considers the impact of road to the ecological space by buffer analysis in ArcGIS.

2.3. Analytic Hierarchy Process (AHP)

As different factors may have a different impact upon the eco-system, it is necessary to represent this point in the calculation process. Thus, in this paper we applied the AHP approach while doing an overlap analysis in ArcGIS. The calculation of the weights of all the factor is explained below.

2.3.1. Determination of Weight of Evaluation Index

In order to determine the weight of each evaluation index, we have consulted 65 experts from both planning and urban geography by questionnaire investigation. They were asked to specify the relative importance of each of the seven factors compared with the others (Table 3). Then, the weight matrix reflecting the relative importance of each of the seven factors are obtained (Table 2). According to this table, the factors' contributing rates (weight value) at this level to ecological sensitivity are: location index (B1): 0.029; terrain status (B2): 0.040; elevation (B3): 0.084; slope (B4): 0.187; hydrological condition (B5):0.421; landscape value (B6): 0.180; road traffic (B7): 0.059.

Table 2. Weight matrix of the impact factors.

Ecological Factors	Location Index	Terrain Status	Elevation	Slope	Hydrological Condition	Landscape Value	Road Traffic	Geometric Mean	Weight Value
Location Index	1	1/2	1/3	1/4	1/7	1/5	1/2	0.290	0.029
Terrain Status	2	1	1/2	1/3	1/7	1/5	1/2	0.410	0.040
Elevation	3	2	1	1/2	1/5	1/3	2	0.858	0.084
Slope	4	3	2	1	1/3	2	3	1.906	0.187
Hydrological Condition	7	7	5	3	1	3	5	4.277	0.421
Landscape Value	5	5	3	1/2	1/3	1	3	1.830	0.180
Road Traffic	2	2	1/2	1/3	1/5	1/3	1	0.595	0.059

Table 3. The scale of relative importance.

A \ B	Extremely Important	Very Important	Important	Slightly Important	Equal	Slightly Unimportant	Unimportant	Very Unimportant	Extremely Unimportant
The evaluation value of A compared with B	9	7	5	3	1	1/3	1/5	1/7	1/9

Remarks: take 8, 6, 4, 2, 1/2, 1/4, 1/6, 1/8 as the median of the above evaluation values.

When the weights matrix is completed, then we calculated the score for each of the sub-evaluation indexes by following Table 4.

Table 4. Single factor weight analysis and ecological sensitive analysis of densely urbanized regions.

Factor Evaluation	Weight	Classification (Sub-Evaluation Index)	Sensitivity	Score
Location Index	0.029	Region at the upwind and/or the upstream and is extremely sensitive	5	0.145
		Region in the central green land of is critical for urban ecology improvement	3	0.087
		Other non-constructive regions can improve urban ecology and it is normally sensitive	1	0.029
Terrain Status	0.040	Natural eco- space (natural reserve, landscape scenic, forest park, etc.)	5	0.2
		Farming and grazing development space (basic farmland, forest land, etc.)	3	0.12
		Urban development space (the built-up areas)	1	0.04
Elevation	0.084	Extremely high terrain in the region	5	0.42
		Relatively high terrain in the region	3	0.252
		Relative flat terrain in the region	1	0.084
Slope	0.187	Steep slope >15°	5	0.935
		Gentle slope 8°–15°	3	0.561
		Flat slope < 8°	1	0.187
Hydrological Condition	0.421	Lakes, rivers	5	2.105
		Buffer zones of lakes and rivers (200–400 m)	3	1.263
		Other	1	0.421
Landscape Value	0.180	High	5	0.9
		Medium	3	0.54
		Low	1	0.18
Road Traffic	0.059	>500 m	5	0.295
		200–500 m	3	0.177
		<200 m	1	0.059

2.3.2. Classification of Sensitivity Level

According to the mathematic evaluation model, it can be inferred that the value range is [0, 9]. By referring to the calculation results, we classified the values into four levels: 0.4–1.5, 1.5–2.3, 2.3–3.2,

3.2–7.2. Each represents a type of the ecological space, namely the insensitive area, weakly sensitive area, sensitive area and highly sensitive area. By this classification, the results are then visualized in ArcGIS (Table 5).

Table 5. Classification of the sensitivity level

Sensitivity Level	Evaluation Value Range	Explanation
Highly Sensitive	3.2–7.2	Normally defined as the surface water or the region with slope >20%, which has high ecological value. It is highly sensitive to constructions and developments. If this kind of region is destroyed, the eco-system would be seriously damaged.
Sensitive	2.3–3.2	Being sensitive to human activities and hard to recover from destruction. It is significant for the eco-system to functions, for the climate and the environment. Therefore, development should be closely scrutinized.
Weakly Sensitive	1.5–2.3	It is capable to accommodate certain human activities. But ecological problems including decrease of air quality, vegetation deterioration and noise would be caused by heavy constructions. If this occurs, it will need a long time to restore.
Insensitive	0.4–1.5	Generally it is OK for a certain degree of developments and constructions. The land can be used for multiple purposes.

2.4. Urban Regime Theory Model as Explanation Framework

The change of the ecological space is mainly due to the rapid development of industrialization and urbanization. The expansion and rapid spread of urban space, as well as the expansion and extension of urban facilities to the periphery, leads to the decrease of the cultivated land area, the erosion of the ecological space and the weakness of the ecological environment.

By studying city development and planning practices in China, Zhang has proposed the urban regime theory (Figure 4) [24]. According to Zhang's idea, the forces that influence the development of the city and the countryside region around it can be divided into three categories: the "government force" which comes from both the local and the central government; the "market power" which is represented by the business parties such as investors, developers and banks; and the "social force" which generally relates to the pressure from the public. Particularly, understanding of the complex interactions among these three parties is of particular concern: the relationship between the central government and the local government in the process of marketization and decentralization; the relationship between the public sectors and non-public sectors; the relationship between the political interests of the central and the local government and the economic interests of the elites. So the evolution of the ecological space in the densely urbanized region during rapidly growing period is an outcome of the gaming between the three parties. In this paper, this explanation framework is applied to explore the underlying mechanisms that shape the ecological space in the Wu-E-Huang-Huang region.

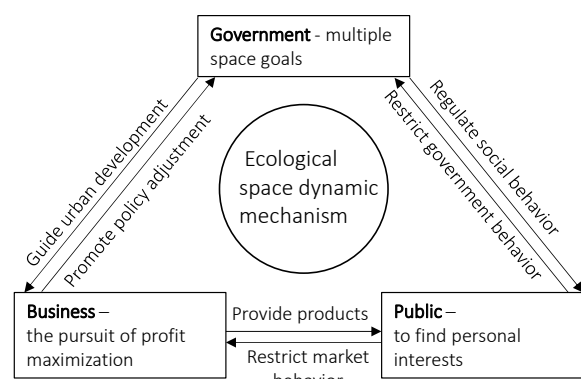


Figure 4. The explanation framework by urban regime theory.

3. Sensitivity Evaluation of the Ecological Space

3.1. Evaluation of the Single Factor's Ecological Sensitivity

The sensitivity score for each factor in each grid is visualized and illustrated by Figures 5–10. It can be seen that most of the region is sensitive as the main part of this region is constituted by rivers, lakes, natural reserves, and scenic landscape, which are defined as the sensitive land-use type.

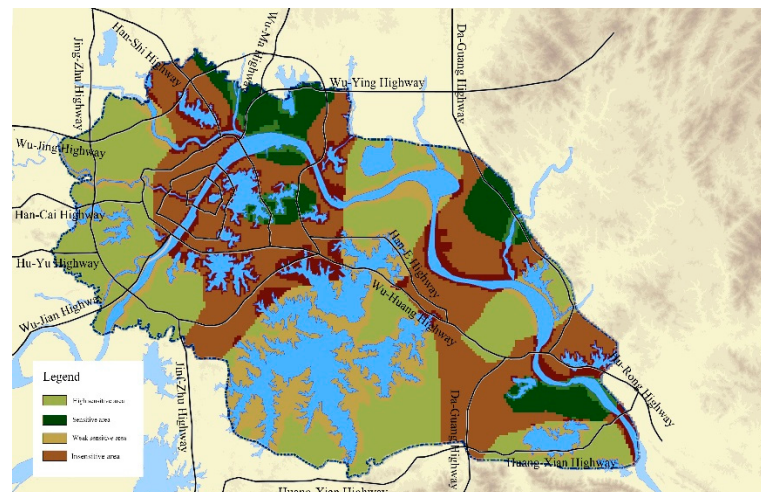


Figure 5. Evaluation of the single factor's ecological sensitivity—Location Index Evaluation. Source: the authors.

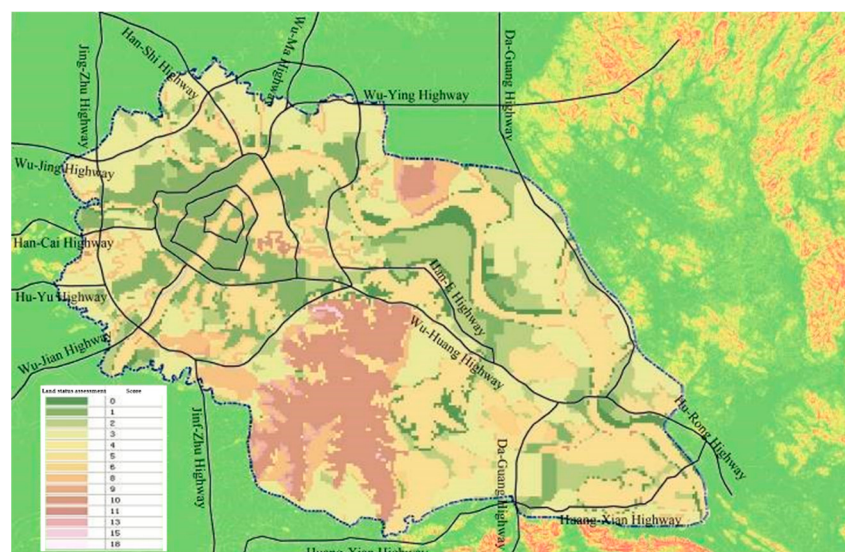


Figure 6. Evaluation of the single factor's ecological sensitivity—terrain status evaluation. Source: the authors.

In terms of location index, the highly sensitive regions are the upstream areas in this region with the potential to be constructed as the ecological corridors for preventing interlocking expansion, which covers 2251.5 km² and 29.58% of the region. The sensitive region, covering 766.25 km² and accounting for 10.07%, is composed by the grassland outside the built-up area of the cities which are significant to the improvement of urban ecology. The other construction lands, not so crucial for ecological improvement, are marked as weakly sensitive regions which cover 1708 km² and take up 22.44% of the region. The insensitive regions are composed of lands for mining, regional infrastructure, urban and village construction. The area of this type is 2885.25 km² and accounts for 37.91% (Figure 5) of the total.

Regarding terrain, the key conservations in Wu-E-Huang-Huang Metropolitan Interlocking Region include natural reserves, forests, landscape scenic, lakes, the Yangtze River and the other rivers, and water conservations [25]. Therefore, these regions are categorized as the highly sensitive regions which cover 48.43% of total area. The sensitive regions, taking up 25.97%, are commonly used for farming and grazing which should be limitedly developed. They include grassland, forestland and basic lands. The rest areas are defined as weakly sensitive regions and insensitive regions which cover 10.55% and 15.06% of the region, respectively (Figure 6).

As shown by elevation analysis, within the Wu-E-Huang-Huang Metropolitan Interlocking Region only 6.23% of it is higher than 80 m (relative to sea level). These areas are classified as the highly sensitive regions covering 474.5 km²; By contrast, merely 8.88% of the study area is subject to sensitive regions, being composed of forestland with an elevation range of 40 m–80 m; the insensitive regions are land with elevation lower than 40 m and the area reaches 4754 km². Considering this status quo, we can infer that terrain is not a critical impediment to constructions and developments. By referring to the evaluation results, for ecological conservation purpose, the focus should be on hilly or mountainous land higher than 40 m (Figure 6). In addition, the slope analysis presents that the highly sensitive regions higher than 15° cover 600.5 km² and take up only 7.89% of the region; the area subject to the sensitive region has a slope between 8° and 15° and covers 1564.75 km², accounting for around 20.56%; the area classified as weakly sensitive regions and insensitive regions accounts for 29.06% and 42.49% respectively (Figure 7). In conclusion, the land resources in sensitive regions with slope higher than 8° should be specially protected because of a much more likelihood of geological hazards.

In terms of hydrological condition, it is vital to avoid water sources from pollution. The water area of the highly sensitive regions, including rivers and lakes and so forth, reach 2071 km² and account for 27.22% of the study area; the buffer areas of the key rivers and lakes are defined as sensitive regions covering 2135.75 km²; the proportion of weakly sensitive regions and insensitive regions composed by the rest areas are 18.29% and 26.43%, respectively. Water resource in the region is crucial, so its protection should be emphasized because it can be easily polluted by urban construction, agricultural production, industrial emission and so forth (Figure 8).

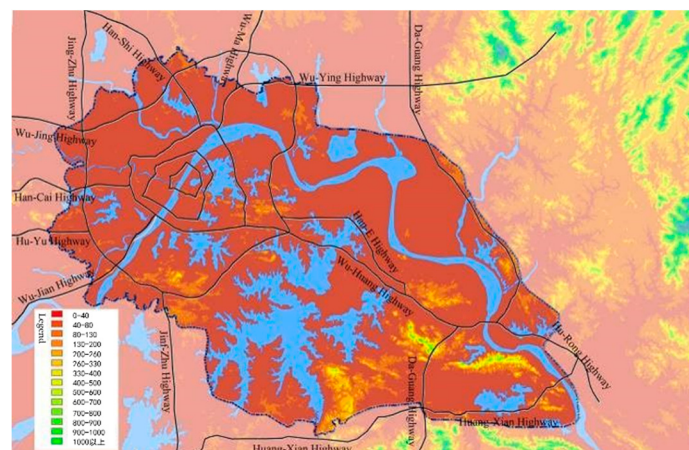


Figure 7. Evaluation of the single factor's ecological sensitivity—elevation evaluation. Source: the authors.

As to landscape value, 32.36% of the natural landscapes and cultural landscapes with the highest value are identified as the highly sensitive regions; 35.46% of total landscapes are sensitive regions that reach 2698.75 km²; the rest areas are grouped as weakly sensitive regions and insensitive regions, accounting for 18.44% and 13.74% respectively (Figure 9).

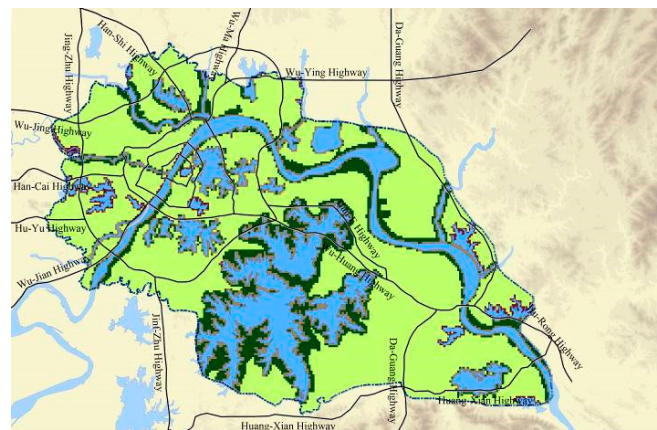


Figure 8. Evaluation of the single factor's ecological sensitivity—analysis of water. Source: the authors.

In terms of road traffic, the highly sensitive regions are composed of highway, railway, and other major transportation channels. The area is 691.25 km², accounting for 9.08% of the region; the sensitive regions is 1049 km² accounting for 13.78%; About 17.41% and 59.73% of the rest regions are sensitive regions and insensitive regions, respectively. So the transportation network to be built including intercity railways, highways and so forth should bypass the highly sensitive regions (Figure 10, Table 6).

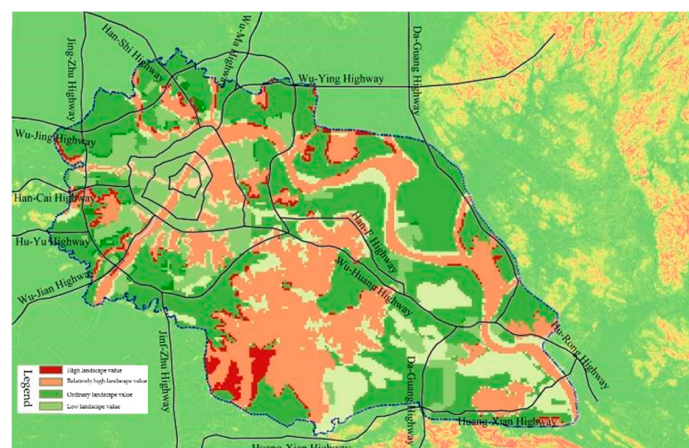


Figure 9. Evaluation of the single factor's ecological sensitivity—landscape evaluation. Source: the authors.

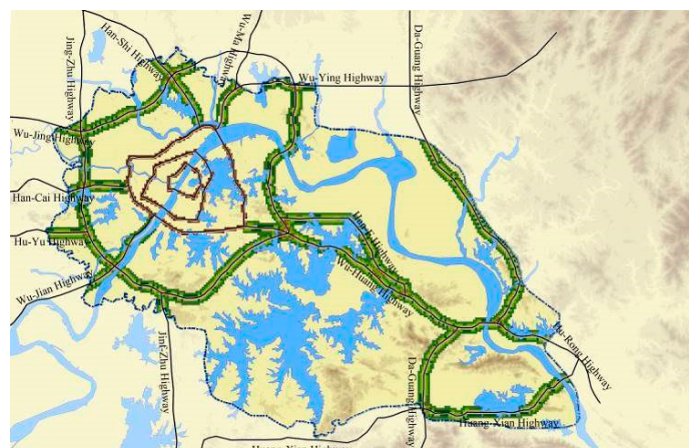


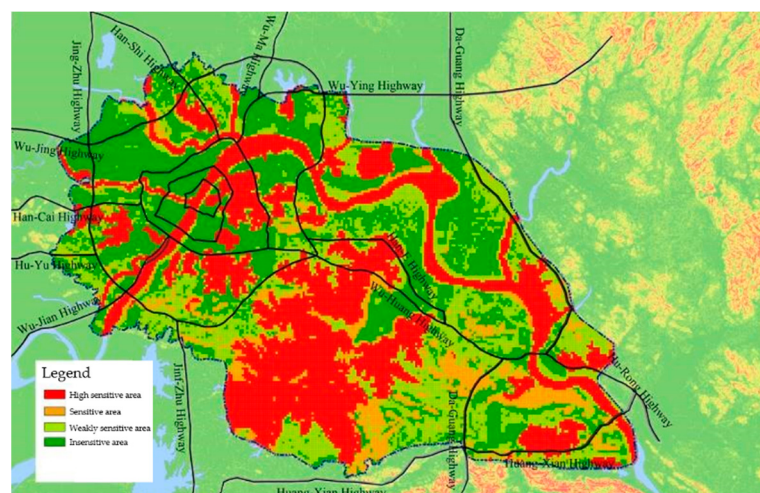
Figure 10. Evaluation of the single factor's ecological sensitivity—road traffic evaluation. Source: the authors.

Table 6. The area of each of the four sensitive levels in the seven factor dimensions in the Wu-E-Huang-Huang Metropolitan Interlocking Region.

Evaluation Factor	Ecological Sensitivity Classification							
	Highly Sensitive		Sensitive		Weakly Sensitive		Insensitive	
	Area (km ²)	Area Ratio (%)	Area (km ²)	Area Ratio (%)	Area (km ²)	Area Ratio (%)	Area (km ²)	Area Ratio (%)
Location Index	2251.5	29.58	766.25	10.07	1708	22.44	2885.25	37.91
Terrain Index	3686	48.43	1976.25	25.97	802.75	10.55	1146	15.06
Elevation	474.5	6.23	675.5	8.88	1707	22.43	4754	62.46
Slope	600.5	7.89	1564.75	20.56	2211.5	29.06	3234.25	42.49
Hydrological Condition	2071.75	27.22	2135.75	28.06	1392.25	18.29	2011.25	26.43
Landscape Value	2463	32.36	2698.75	35.46	1403.25	18.44	1046	13.74
Road Traffic	691.25	9.08	1049	13.78	1324.75	17.41	4546	59.73

3.2. Comprehensive Ecological Sensitivity Evaluation

By overlap analysis of the sensitivity in each of all the factor dimensions, we can generate the comprehensive ecological sensitivity evaluation map. As shown by Figure 11, the area of highly sensitive regions which include the Yangtze River, the lakes and their core wetland zones, and natural reserves and so forth. The total area is 2465.25 km² and takes up 32.39% of the study area. Regions such as the buffer zones of the key rivers and lakes and natural forests are defined as sensitive regions, covering 642.75 km² and accounting for 8.45%. The area of the weakly sensitive regions is 2876 km² which is 37.79% of the region, including forestlands of low elevation, farming lands, etc. The built-up areas of cities, lands used by rural residents, wastelands, quarries, and the alike constitute the insensitive regions, covering 1627 km² and 21.38% of the region (Figure 11, Table 7).

**Figure 11.** Sensitive level of Wu-E-Huang-Huang Metropolitan Interlocking Region. Source: the authors.**Table 7.** Comprehensive ecological sensitivity of Wu-E-Huang-Huang Metropolitan Interlocking Region.

Sensitive Classification	Evaluation Value	Area (Km ²)	Proportion of Researched Area (%)
Highly Sensitive	~3.2–7.2	2465.25	32.39
Sensitive	~2.3–3.2	642.75	8.45
Weakly Sensitive	~1.5–2.3	2876	37.79
Insensitive	~0.4–1.5	1627	21.38

4. Dynamic Mechanism of the Ecological Space Change

4.1. The Explanation Framework to the Ecological Space Change

By referring to the urban regime theory as explained above, the underlying mechanism that lead to the ecological space change and the resulting sensitivity in the Wu-E-Huang-Huang Metropolitan Interlocking Region can be depicted by Figure 12. Roughly, there are three interests parties which are the government, the developers (business) and the public. In this research, the public mainly refers to the new wealthy class and the rural villagers who live on or around the ecological land. Despite both of these two classes are subject to the public, they have different interests which leads to their different attitudes to and actions on the ecological space. The government has two main goals: to keep economic growth, and to provide acceptable living conditions for the residents while at the same time maximize fiscal revenue. To this end, they can use two instruments which are planning and land finance. The developers are profit seekers and they are interested in the taxation support policies initiated by the government. They are also in need of land which can be supplied by the government through land expropriation, a threat to the ecological space and the villagers' interests. In this sense, the government and the developers tend to be in alliance, which as a result will push villagers towards a disadvantaged position. Consequently, land expropriation would be strongly resisted by the villagers. All these interactions happen in this way because China is in great socio-economic transformation. And the Wu-E-Huang-Huang Metropolitan Interlocking Region is particularly the case as it is experiencing an even more drastic change.

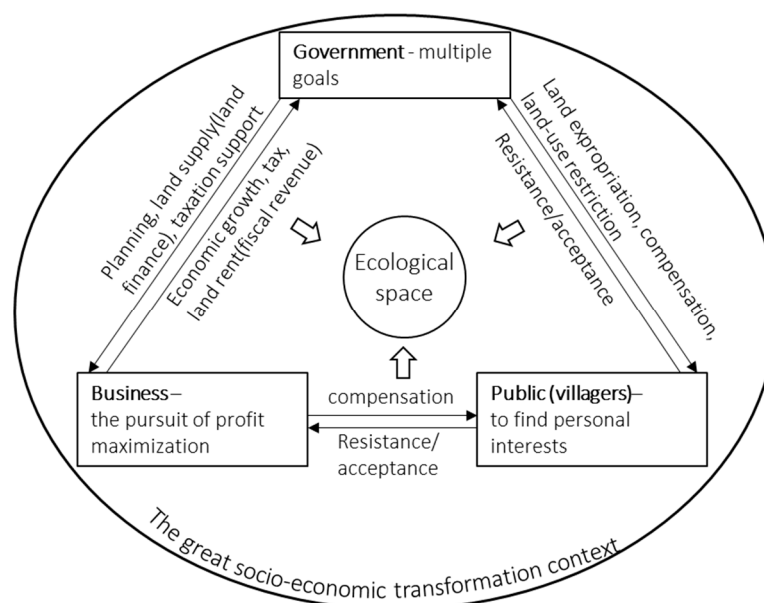


Figure 12. The explanation framework of the underlying mechanism.

4.2. The Great Socio-Economic Transformation as the Context

As has been revealed, China now is at the stage of rapid urbanization. In the last ten years, the urbanization level has been increased by around 1.4% annually, which means that every year there are more than 17 million rural people migrating to cities looking for jobs, housing and other spaces. This is particularly the case in the middle regions of China as the corresponding urbanization pace is even more drastic. Facing this reality and urged by the central government, the local government in these regions are responsible for creating more job opportunities and housing supplies, which provide the reasons and also the opportunities for them to ask for more land quota from the central government.

In addition, under the pressure of globalization and industrial restructuring in China, cities in the Wu-E-Huang-Huang Metropolitan Interlocking Region have to keep a high economic growth speed

while at the same time introduce high-tech industries to this region. As a result, the very old industrial parks which was once the growth engine for cities need to be kept running; and simultaneously new industrial parks aimed at innovation-driven growth, such as high-tech industrial park, scientific park, information industry district and other parks, should be built in response to the innovation-driven growth strategy initiated by the central government of China. This development trend deteriorates the shortage of land supply, which inevitably presents threat to the ecological space surrounding cities.

Furthermore, in parallel with urbanization is the increasing social stratification and the deterioration of the living environment in the central area of cities in the Wu-E-Huang-Huang Metropolitan Interlocking Region. In consequence, high-income groups seek to look for better living quality outside the built-up area of cities and the low-income groups (usually rural villagers and migrants) tend to settle on or around the ecological lands in the suburbs of the urban periphery for lower housing rent. This coupled process strengthens the suburbanization trend and the pressures on the ecological land. Moreover, whereas high-income groups from the central part of cities care much more about the high quality of the ecological environment in the urban periphery, most of the low-income residents on or around the ecological lands of the urban periphery are rural villagers who pay much more attention on the economic value of the ecological lands. Normally, they expect to increase their income by unsustainable ways of exploitation of the resources such as mining, quarrying and selling timber, which incurs strong negative impact on the eco-system in these areas.

4.3. The Land Use Right System and Fiscal System as the Instruments

In China, the land use right system is unique. It is stipulated by law that the land within city administration is state-owned and in the rural region the land is owned by the rural collective. The central idea is that no land is privately owned. Furthermore, collective-owned land cannot be put into the market for trade, which drastically lowers its value. By contrast, the city land (land-use right) can be traded when it is auctioned in the market. Thus, the land price gap between a collective land plot and a city land plot could be massive even if they are adjacent. This potential profit gap gives the local government the momentum to transfer the collective land into city land through land expropriation.

In addition, in the 1990s, in order to exploit the local government's motivation to focus on economic growth, the central government of China launched the power devolution scheme. Regarding taxation, it is legitimized that the local government can keep most of their taxation income and revenue for local development in the condition that they paid the required proportion of tax to the central government. As a result, a land financing system is born because land resources which are directly controlled by the local governments are the most efficient tool to increase the local government's revenue. Because of the massive price gap, the local government can expropriate agricultural or ecological land (such as farmland and forestland) from the villagers by paying them very limited compensation. According to the data published by the Ministry of Land and Resources, land revenue in 2017 was 5 trillion yuan and had increased by 40% compared with that in the same period of the previous year. Moreover, the Development Research Center of the State Council presented that in 2017 in China average revenue of cities from land transfer accounted for 40% of the local fiscal revenue. In other words, guaranteed by the Land Use Right System and driven by the Fiscal System, the ecological space are under unprecedentedly high risk of being encroached by cities.

4.4. The Interests Parties as the Players of the Game

In the last two decades in China, the local government's performance is mainly measured by its economic achievement. As economic performance is closely tied to the local officials' promotion [22], local governments aspire to cooperate with the 'economic elites' to escalate their performance via investments and to alleviate all kinds of interest conflicts through economic growth [23]. Firstly, each local government in densely urbanized region develops the local economy on its own interests without concerning the overall wellbeing of the entire region. Additionally, attracted by the unique land rent

advantages in the urban periphery, numerous investments and varied kinds of development zones are directed into this area in response to the new wave of high-tech park construction.

In order to facilitate this development trend, different kinds of plans as the ambitious blueprints for the local government are formulated and legally approved. As a department of the local government and constrained by the hierarchical administration system, the plans have to reflect the prime leader's (normally the General Party Secretary) idea and vision of the development of the city. In addition, in the planning system, it is not legally compulsory for the Planning Department of the local government to make specific plans for eco-safety and environment protection. So, these two aspects are commonly ignored even though they have been stressed for years. In consequence, the plans always try to pave the way for urban land expansion and in consequence threatening the eco-land/farming land which is usually legally administered by the Environment, the Land Resource or the Agricultural Departments. Even though the Planning Bureau may try to balance interests between these parties, it is hard to achieve because different governance powers are simultaneously shared by these Departments on the same land plots. To avoid power and profit drain, each department fights for its own interest and thus form a fragmented land-use pattern and regional governance.

In order to keep high economic growth and generate more revenue, the local government would like to welcome developers to buy land-use rights and invest as much as possible. In addition, the financial banks are also needed by both the developers and the government. So it is very likely that they three can form a growth alliance through which land financing can be executed. In fact, during this process, with the aim to attract more developers, the local government tend to run massive scale of infrastructure constructions which are mainly supported by the funds from land mortgage and government's unsecured loans. In some administrative counties in the eastern part of China, 60%, even 70% of tens of billions of infrastructure construction funds come from the mortgage of land-use right.

Regarding the counties in the Wu-E-Huang-Huang Metropolitan Interlocking Region, constrained by the commonly poor economic basis but pressed by the high economic goals designated by the upper-tier of government, land financing becomes the only funding support to build industrial parks with the expectation to achieve economic development goals. The developers are always smart and they can see lucrative opportunities from land acquisitions and demolitions because property developers can obtain excessive profits from expensive housing price after they buy parts of those acquired lands from the government and develop real estate by lobbying the local government to allow higher development density. Because of the huge value gap, the urban periphery is always viewed as the prior region by those developers given the low compensation for land acquisition and the high-profit potential.

In this process, the villagers as a collective—the real owners of the land defined as the ecological spaces—are actually excluded by the growth alliance. As the land is collectively owned, the villagers as individuals have no reasonable right to claim profit by law. Thus, if they want to have their profit claimed, they have to do it in a collective way. That is, the collective have to negotiate with the upper-tier local government. But, this is not easy as no one wants to act as the representative if the potential risk cannot be balanced by the potential gain. But, the potential gain is always full of uncertainty. To avoid loss of interests, normally these villagers will not go to talk with the government. Instead, they tend to resist land expropriation and build numerous private apartments and houses or run land-lease, mining factories and quarries in the ecological spaces. Consequently, the regional ecological space is undermined, turning the ecological and the agricultural land into an even more sensitive space.

5. Conclusions

China is now still experiencing rapid urbanization even though the speed in the eastern part is slowing down. Yet, drastic urbanization is still the theme-tune in middle China, particularly exemplified by the Wu-E-Huang-Huang Metropolitan Interlocking Region. As rapid urbanization in China is achieved at the cost of encroaching farmland and even forests which are crucial to the eco-system, and

particularly the well-functioning of the eco-system, it is urgent that we have to evaluate the sensitivity of the ecological space to human activities so that a more environment-and-eco-system-friendly planning approach and system can be applied. With this end, this paper presents a grid-based approach to evaluate the sensitivity of the ecological space in the study area. It provides a $0.5\text{ km} \times 0.5\text{ km}$ spatial granularity which fundamentally improves the applicability of the analysis results to planning practices as it is much smaller than the bottom-level administrative unit, the village. In this sense, the responsibility to conduct ecological conservation in each grid can be specified to certain administrative parties or groups.

Overall, the evaluation results show that around 41% of the region is subject to high sensitivity. In addition, due to the rapid expansion of the built-up areas, many parts subject to insensitive areas are adjacent to the sensitive or even highly sensitive areas. This is in fact, as explained by Section 4, caused by the very complex interactions among the three different parties (the government, the business groups and the public). This outcome implies that the development of these regions have to seriously consider the pressing demand of ecological restoration and conservation. That is, much more emphasis has to be included in the planning and development scheme for this region in the future. Yet, as this region is still in rapid urbanization, the central point is that land acquisition for urban development has to be conducted by referring to the ecological sensitivity evaluation results but not only the location value of the targeted sites.

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