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A Quantitative Analysis on the Coordination of Regional Ecological and Economic Development Based on the Ecosystem Service Evaluation

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Abstract: The coordination between regional ecological and economic development has become a crucial topic in current environmental and development research due to the establishment of sustainable development goals and the acceleration of urbanization. In this study, an improved eco-economy coordination (EEC) model is proposed to evaluate the coordination of regional ecological and economic development. This study focuses on Wuhan, China, and utilizes socioeconomic and remote sensing data from 2000 to 2015 to measure both static and dynamic ecosystem service values (ESV). ESVs are the direct and indirect benefits produced by ecosystems that support human survival and development. The calculated ESVs are then integrated into the ecological–economic coordination (EEC) evaluation. This study aims to conduct a comparative analysis of the ecological-economic coordination across various districts of Wuhan, with a focus on spatiotemporal factors. In addition, this paper highlights the role of environmental adjustment coefficients in enhancing the EEC assessment. The results show that (1) the total static ESV experienced a loss of RMB 1.2 billion (approximately USD 169 million) and showed a decreasing trend, while the dynamically corrected ESV reversed this trend; and (2) EEC based on static ESV showed a low degree of conflict between ecological and economic reconciliation compared with a significant increase in EEC based on dynamic ESV. Based on static ESV, the EEC showed a low degree of conflict between ecological and economic reconciliation compared to a significant increase in EEC based on dynamic ESV. After being corrected by environmental adjustment coefficients, the EEC values showed a more differentiated distribution. Most regions demonstrated an overall upward trend in EEC, with a few, such as Wuchang District and Jiang'an District, being notable examples. However, Jianghan District presented a high conflict status. Finally, a series of decision-making suggestions are given based on relevant study results, and an important policy implication is that the coordination of economic growth and ecological protection, under large downward pressure from EEC values, needs to be paid special attention in policy decision-making.

Keywords: eco-economy coordination; ecosystem service value; environmental adjustment coefficient; willingness to pay

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1. Introduction

Since the reform and opening up in 1978, China has experienced rapid economic development and urbanization. China's GDP has increased from CNY 406.2 billion in 1979 to CNY 1561.61 billion in 2020 [1]. However, the rapid economic development has also led to a series of ecological and environmental problems, such as the aggravation of air pollution, especially the aggravation of haze pollution; the shortage of resource consumption, etc.; as well as a series of social problems, such as unbalanced regional development and the widening gap between the rich and the poor [2,3]. Against the backdrop of the United Nations' Sustainable Development Goals (SDGs), the coordinated development of socio-economic and ecological systems has become a popular topic in the field of sustainable development. The positive interaction between social economy and ecological environment is closely related to the level of sustainable development [4] and is also an important indicator to measure whether regional development is healthy or not [5].

Land ecosystems have both natural and social-economic attributes and are the result of a comprehensive coupling between natural and economic systems [6]. Land use/land cover change has a broad impact on land ecosystems [7,8]. For example, rapid urban expansion that has occupied a large amount of ecological land such as grassland, water area, forest, and cultivated land to meet the needs of construction may cause land desertification, land secondary salinization, land impoverishment, and other land ecological quality problems [9], thereby leading to the destruction of land ecosystems [10,11]. Land use/land cover records the extent to which human activities affect the natural environment [12]. The ecological effects of land use change can be measured from ecological footprint [13], eco-environmental quality index [14,15], biodiversity change [11], and ecosystem services [16–19]. Ecosystem services (ES) are the benefits that ecosystems provide for human survival and sustainable development [20]. The services provided by ecosystems include provisioning, regulating, supporting, and cultural services [21,22]. The concept of ecosystem services (ES) was first introduced by SCEP in the 1970s. Since then, research on the classification of ecosystem services has gradually emerged [23]. This includes the Millennium Ecosystem Assessment [22], the Nature's Contributions to People framework [24], and the continuously updated Common International Classification of Ecosystem Services (CICES) [25]. Scholars have conducted exploratory studies on the valuation of ecosystem services (ESV) [21,26–29], building on the foundation of ecosystem service classification research. The methods for estimating ESV (Ecosystem Service Value) can be broadly divided into two categories. There are two methods for estimating ESV: the unit value method, which calculates ESV based on the economic value per unit area of the ecosystem [21,26,30], and the functional value method, which is based on calculations from a single service function [28]. In recent years, scholars have extensively evaluated ecosystem service values in areas such as cities, watersheds, and ecological reserves using ESV (Ecosystem Service Value) assessment methods [31,32]. These studies are mostly based on land use data and incorporate spatial technologies to explore the coupling relationship between land use changes and ESV [33]. Ecosystem services are defined as the benefits generated by ecosystems that directly or indirectly support human survival and development [21,34]. Most ecosystem services have public characteristics that do not have market-oriented value and are easy to over-consume [21,35,36]. To realize the sustainable development of human beings, it is necessary to evaluate the value of ecosystem services and, therefore, establish a bridge between the market value of ecosystem services and the socioeconomic development [37]. Land use changes inevitably lead to the change of ecosystem services [38,39]. For instance, agricultural expansion and deforestation have resulted in a significant increase in soil erosion rates. Urban expansion has led to a substantial reduction in water fields and paddy fields, resulting in a loss of biodiversity. The urgent demands of food supply and economic development have caused a large amount of woodland to be converted into farmland, which has subsequently been transformed into construction land [40–44]. These human activities lead to the gradual reduction of ecosystem services, and may cause the aggravation of ecosystems imbalance and an increase in restoration costs [45,46]. Maintaining and protecting ecosystem services is the foundation of sustainable development [12,38]. Analyzing the interaction between the ecological service value of land use and regional economic development has a great influence on adjusting land use structure and promoting economic development [17,47].

The measurement of coordination degree of an eco-economic system is one of the hotspots of sustainable development fields [48]. Quantitative evaluation of coordination between a social economic system and a natural ecosystem can provide a relevant theoretical basis for the realization of sustainable development [14]. At present, relevant methods to measure the coordinated development of ecological and economic systems include emergy analysis, material flow analysis, system dynamics model [49,50], ecological footprint analysis [50], market value method, and sustainability evaluation method [51]. However, the applicability of these approaches is still limited by external ecological and socio-economic factors and the accuracy of regional spatial analysis [52]. In addition, as the coordinated development of the environment and economy involves many fields such as ecology, economy, and geography that are characterized by comprehensiveness and complexity, although the current research has achieved excellent achievements, the quantitative evaluation is still in the exploratory stage and needs to deepen quantitative analysis [53].

Supported by remote sensing and geographic information system (GIS) technologies, the eco-economy coordination (EEC) model was used to evaluate the coordination of regional ecological and economic development [28]. The EEC model was proposed by [54] to measure the coordination between ecological and economic development of a region through quantitative analysis. This model has been widely used to assess the degree of coordination between ecology and economy. In [55], they studied the scope of ecological compensation in a fragile oasis in China by measuring the ecological–economic coordination index. According to this model, [56] conducted a quantitative study on the level of ecological–economic harmony in Harbin by quantifying land use/cover change (LUCC). Because ecosystem services can reflect the interaction, mutual influence, and synergistic evolution of land use and ecosystems, as well as the close interaction between land use and economic development, ESV is used to describe the ecological environment. The impact of land use on regional economic development can be revealed by evaluating the ecological service and the excessive consumption of ecosystem services can restrict regional economic development [57]. The objective of this study was to calculate the ecological–economic coherence (EEC) based on static and dynamic ecosystem service values (ESV). This will improve the reliability and accuracy of the assessment results. Static ESV is the assessment of ecosystem services related to ecosystem structure and function, and its changes represent the variations of human well-being [21]. The application of the static ESV in EEC assessment can fully reflect the restrictive relationship between ecosystem services, human welfare, and social-economic development. Dynamic ESV is the assessment of ecosystem services at different stages of social development and its changes represent the impact of people's understanding of the ecological environment and changes in demand on ecosystem service benefits [19]. Applying it to EEC assessment can help us better understand the role of dynamic changes of ESV in promoting the coordinated development of eco-economy.

However, the traditional EEC model still has certain limitations, mainly because it can only analyze whether the ecological environment of a certain area is improved or not and whether the development lags behind through the vertical comparison in different periods [58]. Nevertheless, it is necessary to conduct a comprehensive study on the coordinated development of ecological economy in a region by comparing and analyzing the differences of spatial geography and regional economic level of all subregions. Hence, to make EEC comparative analysis more objective, this paper proposed an environmental adjustment coefficient to improve this situation. Taking Wuhan as a study object, this paper quantitatively evaluated the variation of static and dynamic ecological service values of land use, and further explored the coordinated development level and spatial differences between regional ecological environment and economic development. On this basis, the interaction mechanism and evolution law of economic development and ecosystem services were analyzed, and the coordinated development of ecological economy in Wuhan was comprehensively analyzed from the perspectives of vertical analysis and horizontal comparison.

2. Materials

2.1. Study Area

Wuhan, located at 30°35′36′′ N, 114°18′17′′ E (Figure 1), is one of the fastest growing cities and the largest city in the center China. The compound annual growth rate of the gross domestic product (GDP) is over 14%. The GDP increased by 803.7% from 2000 to 2020. The permanent resident population of Wuhan was 11.21 million in 2020, an increase of 18.6% compared to 7.492 million in 2000 [1]. In 2020, a large-scale COVID-19 event broke out in Wuhan. As the city with the longest containment period, the latest resumption, and the greatest impact of the epidemic, Wuhan's GDP dropped by 40.5% in the first quarter of 2020. However, through the implementation of a series of favorable economic development policies, the strong economic growth eventually turned positive, with the total amount reaching CNY 1561.61 billion, ranking among the top ten cities in China [1]. In 2021, Wuhan's GDP exceeded CNY 1.77 trillion, with a year-on-year growth of 12.2%, and the per capita disposable income of urban and rural residents in Wuhan was CNY 55,297 and CNY 27,209, respectively, an increase of 9.8% and 13.1% compared with 2020. Wuhan has experienced rapid urbanization and the urbanization rate of registered population reached 84% in 2020. However, rapid urbanization has also brought a series of environmental problems, such as haze pollution, water pollution, and so on. The outstanding performance is the "spreading the cake" urban expansion mode, occupying a large amount of the natural landscape, especially large-scale high-quality arable land, resulting in the degradation of the natural ecosystem, and affecting the supply of ecosystem services. Hence, this paper chose Wuhan as a case study to explore the coordination between economic development and eco-environmental transformation in Wuhan.

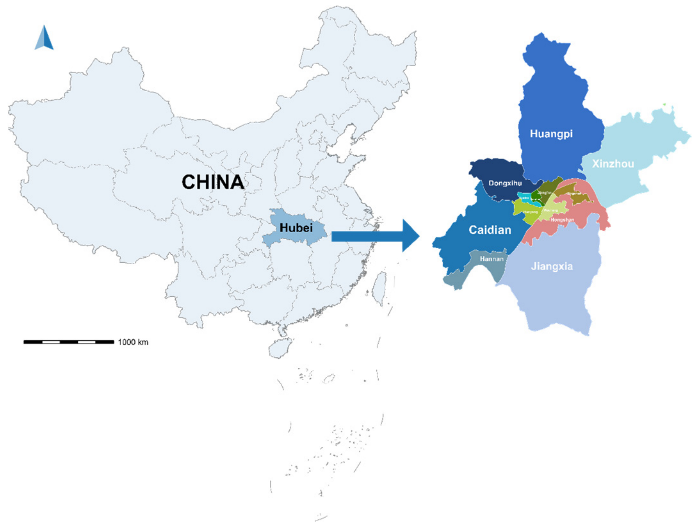

Figure 1. The study area.

2.2. Data Sources

The data mainly covered socio-economic data and remote sensing image data. The remote sensing image data were all from the Resource and Environment Science Data Center of Chinese Academy of Sciences [59]. It included the four periods of land use classification maps from 2000 to 2015 and an administrative division map of Wuhan city and its subordinate counties. In addition, it also included the maps of Chinese net primary productivity distribution, which was calculated by using a Light Energy Utilization Model. The social and economic data sets included permanent resident population, GDP and Engel coefficients were from Wuhan Statistical Yearbooks. The price of Japonica rice, Indica rice, corn, and soybeans was taken from the China Price Statistics Yearbook and the China Agricultural Product Price Survey Yearbooks, with all prices adjusted to the 2000 price level. The residential garbage treatment fee was taken from the service fee standard of Wuhan municipal household garbage [60]. The treatment fees of wastewater and waste gas were taken from China Statistical Yearbooks. The treatment cost of industrial wastes was obtained from Statistical Bulletin of Ecological Environment of Wuhan.

3. Methods

3.1. Ecosystem Services Valuation

The equivalent factor method proposed by [21] is widely used in evaluating ecosystem services [61], which is only associated with structure, function, and process, while the dynamic ESV evaluation needs to modify spatial heterogeneity of ecosystem services and the willingness to pay (WTP) changing with the social development. Based on the traditional evaluation method of ESV, this paper constructed the spatial heterogeneity coefficients and social development stage coefficients to adjust the dynamic ESV assessment, and analyzed the structure and characteristics of ecosystem services from the spatio-temporal variation of static ESV and dynamic ESV.

3.1.1. Evaluation of Static ESV

Static ESV is usually calculated based on land area and land use type, but many studies set the ESV of construction land as 0, ignoring the negative impact of construction land on ecosystem services such as gas regulation, environment purification, and other ecosystem service functions [62–64]. Therefore, this paper evaluated static ESV from two aspects: construction land and non-construction land.

The non-construction land included dry land, paddy field, wetland, waters, woodland, and grassland, and the ESVs of these land ecosystems were calculated as follows [21].

$$\mathrm{ESV_n} = \sum_i \sum_j \mathrm{A_j} \times \mathrm{VC_{ij}} \quad (1)$$

where $\mathrm{ESV_n}$ is the ecosystem service value of non-construction land, $\mathrm{A_j}$ is the area of land use type j, $\mathrm{VC_{ij}}$ is the value equivalent of land use type j with ecosystem service i, which is determined according to the equivalent factors of [65] presented in Table 1 and the actual grain yield of Wuhan.

Table 1. Value coefficients of non-construction lands in Wuhan (Yuan/ha).

Ecosystem Classification		Paddy Field	Dry Land	Woodland	Grassland	Waters	Wetland
Supply services	Food production	2029	1268	433	567	1194	761
	Raw material	134	597	985	836	343	746
	Water supply	−3925	30	507	463	12,371	3865
Regulation services	Gas conditioning	1656	1000	3238	2940	1149	2835
	Climate regulation	851	537	9700	7775	3417	5372
	Waste treatment	254	149	2880	2567	8282	5372
	Hydrological regulation	4059	403	7073	5700	152,567	36157
Support services	Soil conservation	15	1537	3954	3581	1388	3447
	Nutrient cycle	284	179	298	269	104	269
	Biodiversity conservation	313	194	3596	3253	3805	11,744
Cultural Services	Aesthetic landscape	134	90	1582	1433	2820	7058

Notes: Wetland refers to marshland, swampland, and beach. Waters refers to terrestrial aquatic ecosystems including natural river, lake, ditch, and canal, etc.

The ESVs of gas regulation, water supply, and waste disposal of construction land were calculated based on the method of [66,67], and the ESV of aesthetic landscape was calculated by using the market value method. The details are as follows:

The calculation formula for the ESV of gas regulation in construction land is:

$$E_q = -\frac{C_q}{S} \quad (2)$$

where E_q is the ecosystem service value of gas regulation per unit area of construction land, C_q is the cost of waste gas treatment, and S is the total area of construction land.

The calculation formula for the ESV of water supply in construction land is:

$$E_w = \frac{-(C_w + WP_w)}{S} \quad (3)$$

where E_w represents the ecosystem service value of water supply per unit area of construction land, C_w is the cost of wastewater treatment, W is the total water consumption, and P_w is the price of water supply (the unit price of residential water supply is CNY 1.52/ton, and that of non-residential water supply is CNY 2.35/ton).

The calculation formula for the ESV of waste disposal in construction land is:

$$E_d = \frac{-(C_r + C_c)}{S} \tag{4}$$

where E_d is the ecosystem service value of waste disposal per unit area of construction land, C_r is the fee of resident waste treatment, C_c is the cost of industrial waste treatment, and S is the area of construction land.

The calculation formula for the ESV of aesthetic landscape in construction land is:

$$E_a = \frac{C_t}{S} \tag{5}$$

where E_a is the ecosystem service value of aesthetic landscape per unit area of construction land, C_t is the operating revenue of tourist attractions, and S is the area of construction land.

3.1.2. Evaluation of Dynamic ESV

The net primary productivity, as the quantitative value of the final product of land, is positively related to eight types of ecosystem services such as gas regulation, grain production, raw material, etc. [65]. So, the net primary productivity is used to construct spatial heterogeneity coefficient as follows:

$$\mathrm{Q} = \frac{\mathrm{NPP_{wh}}}{\mathrm{NPP_{na}}} \tag{6}$$

where Q is the spatial heterogeneity coefficient, and $\mathrm{NPP_{wh}}$ and $\mathrm{NPP_{na}}$ are the average values of net primary productivity of Wuhan and China, respectively.

Pears S growth curve, a general method to express the coefficients of social development stages, can be used to modify the static ESV in different stages of social development [3,68,69]. Its formula is as follows:

$$l = \frac{1}{1 + \mathrm{e}^{-(1/E_n - 3)}} \tag{7}$$

where l is the coefficient of social development stage, and E_n is Engel's coefficient.

The above calculated coefficient l is less than 1, meaning that the dynamic ESV after correction is much smaller than that of static ESV. This is contrary to the common cognition that economic and social strides can promote the growth of willingness to pay for ecological environment [70]. Because the average price of static ESV was calculated at the 2000 price level, the ratio of social development stage coefficients in other years and that of 2000 was used to further revise the social development stage coefficient:

$$D_h = \frac{l_h}{l_{2000}} \tag{8}$$

where l_h is the social development stage coefficient in h year, and D_h is the modified social development stage coefficient.

Finally, the dynamic ESV is estimated as below:

$$\mathrm{ESV}_d = \mathrm{Q} \times D_h \times \mathrm{ESV}_s \tag{9}$$

where ESV_d is dynamic ecosystem service value, D_h is the revised social development stage coefficient, Q is the spatial heterogeneity coefficient, and ESV_s is static ESV.

3.2. Ecological and Economic Coordination Index (EEC) Model

The EEC model was first proposed by [54] to measure whether the ecological and economic development of a region is coordinated through quantitative analysis. ESV is used as an indicator of the ecological environment and GDP is used as an economic indicator. The general form of the EEC model is as follows:

$$\text{ESV}_{pr} = \frac{\text{ESV}_{pn} - \text{ESV}_{pm}}{\text{ESV}_{pm}} \tag{10}$$

$$\text{GDP}_{pr} = \frac{\text{GDP}_{pn} - \text{GDP}_{pm}}{\text{GDP}_{pm}} \tag{11}$$

$$\text{EEC} = \frac{\text{ESV}_{pr}}{\text{GDP}_{pr}} \tag{12}$$

where ESV_{pn} and ESV_{pm} are the ecosystem service values per unit area in the later and earlier period of the study area, respectively; GDP_{pn} and GDP_{pm} are the GDP per unit area in the later and earlier stages of the study area, respectively; and ESV_{pr} and GDP_{pr} refer to the change rate of ESV and GDP, respectively.

Improvement of EEC Evaluation

The above EEC model can only analyze whether the ecological environment of a certain area is improved or not and whether the development lags behind through the vertical comparison in different periods. The difference of ESV between regions is ignored whether it is calculated based on static ESV or dynamic ESV. The EEC calculated in this way is not appropriate to compare the development of districts horizontally. This paper proposed an environmental adjustment coefficient to improve this situation. The ratio of regional to national ESV was used to construct the environmental adjustment coefficient. In addition, the ESV per unit area was adopted for avoiding the difference of ESV caused by land area changes in different districts. The formula is as follows:

$$\text{E} = \left(\frac{\overline{\text{ESV}_{\text{pm}}}}{\overline{\text{ESV}_{\text{tm}}}}\right)^{\text{SIGN}(\overline{\text{ESV}_{\text{pm}}})} \tag{13}$$

where E is the environmental adjustment coefficient; $\overline{\text{ESV}_{\text{pm}}}$ and $\overline{\text{ESV}_{\text{tm}}}$ are the ecosystem service values per unit area of the study area and the whole country in m period; and SIGN is the judgment symbol, when $\overline{\text{ESV}_{\text{pm}}}$ is greater than 0, the value is 1, on the contrary, it is -1.

Accordingly, the revised EEC model is shown as follows:

$$\text{EEC}_{\text{a}} = \text{EEC} \times \text{E} \tag{14}$$

where EEC is the original ecological and economic co-ordination index model, calculated from Equation (13), and E is the environmental adjustment coefficient, calculated from Equation (12).

In this paper, the static and dynamic ESV of Wuhan were comprehensively assessed and the EEC was estimated based on the static ESV and dynamic ESV, respectively, and a comparative analysis was also conducted. According to the study of [54], the specific connotation and classification of the EEC index is summarized in Table 2.

Table 2. The connotation of EEC index.

Classification	Descriptions
EEC ≥ 1	The ecological environment preservation and economic growth are in a state of high coordination
0.8 ≤ EEC < 1	The ecological environment preservation and economic growth are in a state of relatively moderate coordination
0.6 ≤ EEC < 0.8	The ecological environment preservation and economic growth are in a state of moderate coordination
0.4 ≤ EEC < 0.6	The ecological environment preservation and economic growth are in a state of relatively low coordination
0.2 ≤ EEC < 0.4	The ecological environment preservation and economic growth are in a state of low coordination
0 ≤ EEC < 0.2	The ecological environment preservation and economic growth are in a state of potential crisis
−0.2 ≤ EEC < 0	The ecological environment preservation and economic growth are in a state of low conflict
−0.4 ≤ EEC < −0.2	The ecological environment preservation and economic growth are in a state of relatively low conflict
−0.6 ≤ EEC < −0.4	The ecological environment preservation and economic growth are in a state of moderate conflict
−0.8 ≤ EEC < −0.6	The ecological environment preservation and economic growth are in a state of relatively high conflict
−1 ≤ EEC < −0.8	The ecological environment preservation and economic growth are in a state of high conflict
EEC ≤ −1	A deteriorating relationship between ecological environment preservation and economic growth

Notes: EEC is eco-economy coordination.

4. Results

4.1. Analysis of ESV

4.1.1. Variation of the Static ESV

Figures 2 and 3 show the values and percentages of various types of land ecosystem services in Wuhan from 2000 to 2015. The ESV of Wuhan experienced a process of first rising and then falling, with the total ESV decreasing by CNY 1.242 billion. But, the percentage change was not all decreased. The percentage of woodland in total value increased by 0.122%, which is closely related to the policy of returning farmland to forests. The value of the water area increased by CNY 806 million, and the percentage increased by 5.865%, which was obviously positively affected by the policies of returning farmland to the lake. The value change of wetland showed a trend of decreasing first and then increasing, with a total change of CNY −256 million, a percentage decrease of only 0.19%, which is closely related to the gradual implementation of wetland protection projects. The ESVs of paddy fields and dry land experienced a decline. The value of ecosystem services provided by construction land was negative and expanding constantly in quantity, and the decline in its ESV was greater than the total decrease in ESV of other land ecosystems. In brief, although Wuhan has benefited from various ecological protection policies and improved its ecological environment, the ecosystem services still face considerable downward pressure and need to be further improved.

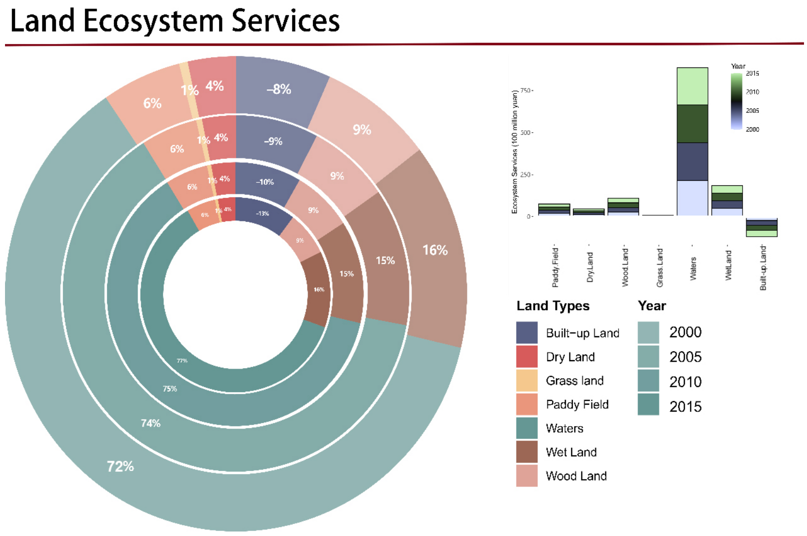

Figure 2. Values and percentages of various types of land ecosystem services in Wuhan from 2000 to 2015 (CNY 100 million). Notes: The total value of each ring in the chart is 100%.

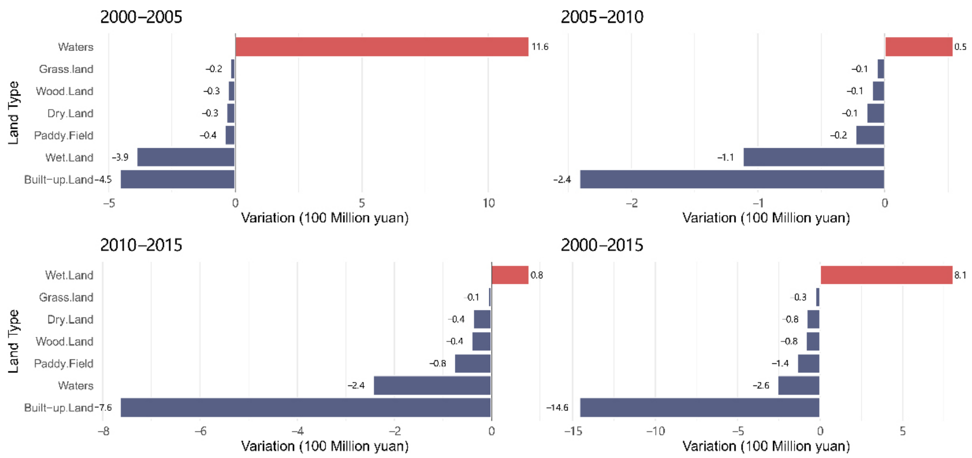

Figure 3. Changes of various types of land ecosystem services in Wuhan from 2000 to 2015 (CNY 100 million).

Figures 4 and 5 show the levels and changes of ESV for different ecosystem services of Wuhan from 2000 to 2015. The ecosystem services in Wuhan were dominated by hydrological regulation and supplemented by other services. Hydrologic regulation contributed the most to the total ESV; its ESV accounted for more than 70% of the total ESV in four study periods. In contrast, the ESV of water supply suffered the most loss. This is because to the large-scale increase in construction land led to a huge increase in industrial and residential water consumption. In addition, the dry field irrigation also imposed a certain load of water supply. The ESV of esthetic landscape raised year by year, the main reason is that the esthetic landscape provided by construction land increased continuously. Overall, the ESVs of all ecosystem services changed in a negative direction and showed an expanding trend except the esthetic landscape and hydrologic regulation services.

4.1.2. Variation of the Dynamic ESV

After the revision, the dynamic ESV was, respectively, 1.52-, 1.52-, 1.61-, and 2.06-fold compared to static ESV in four periods. Moreover, the dynamic ESV variation presented a downward–upward–upward trend, which is the opposite compared to static ESV. These reflected that the social and economic development and changes were very drastic and meanwhile the people's willingness to pay for ecological environment improved significantly. Most notably, the magnitude of ESV changes varied in different periods. The most dramatic changes occurred in the period 2010–2015, which implied that the dynamic ESV increased rapidly, but meanwhile the static ESV also experienced a huge loss during this period of rapid urbanization.

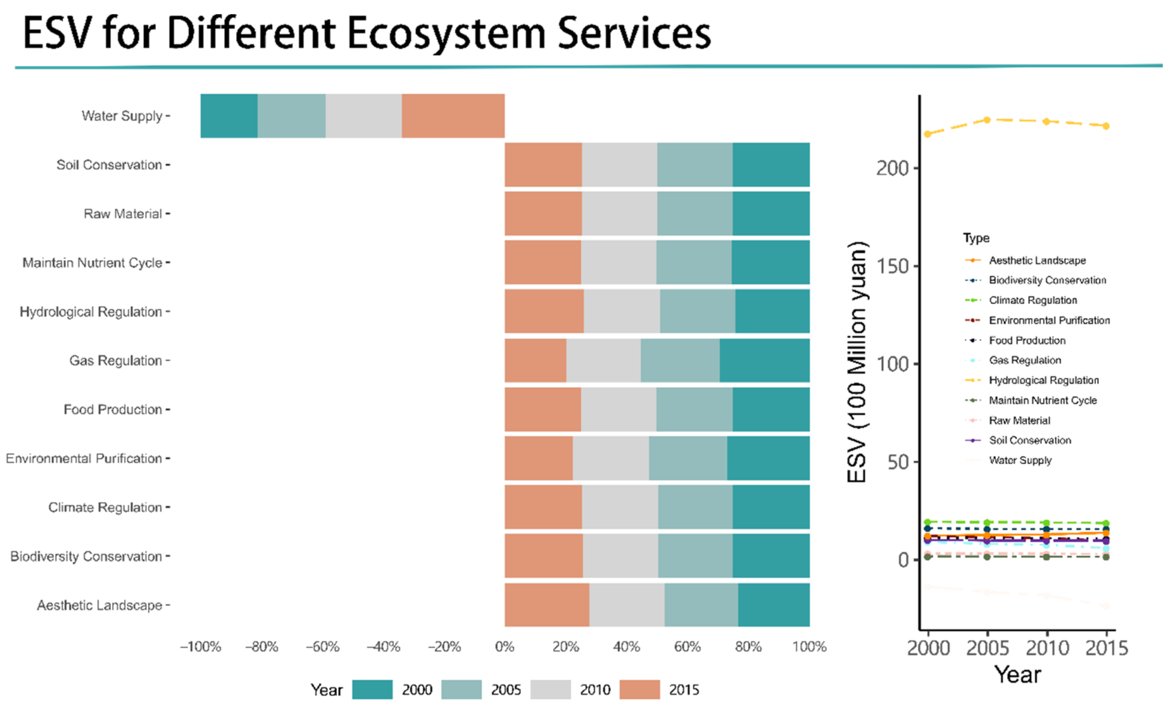

Figure 4. Values and percentages of ESV for different ecosystem services from 2000 to 2015 in Wuhan (CNY 100 million).

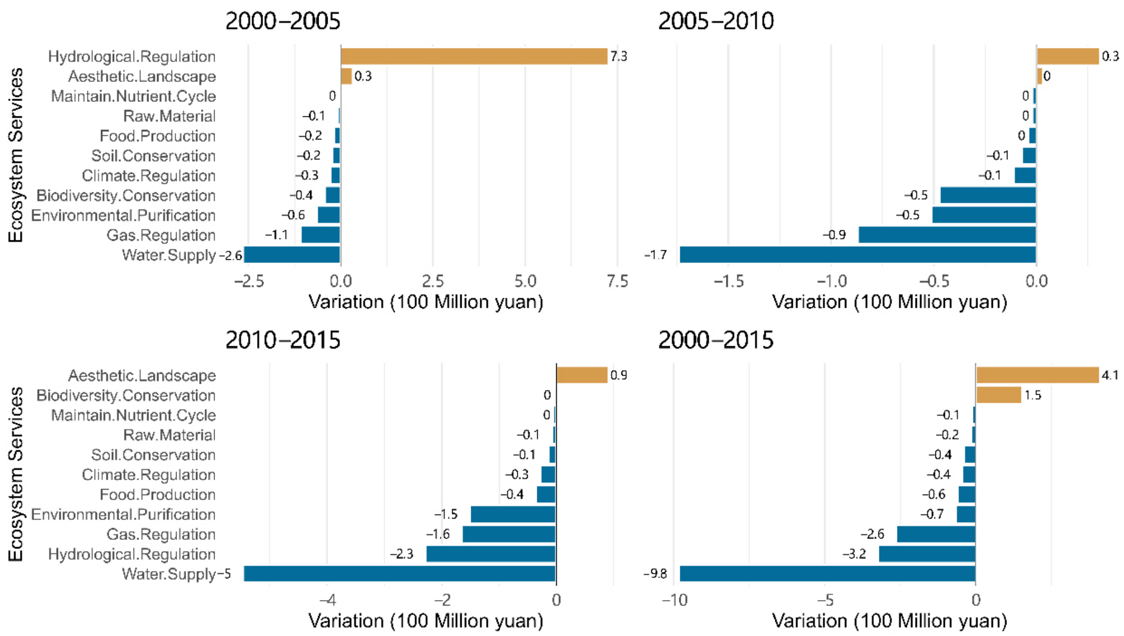

Figure 5. Changes of ESV for different ecosystem services from 2000 to 2015 in Wuhan (CNY 100 million).

All ecosystem services, except for aesthetic landscape and hydrological regulation, experienced a process of decline first and then rise. The ESV of hydrological regulation and aesthetic landscape services kept rising, mainly affected by the expansion of the areas of waters and construction land. The ESV of water supply services was negative and the loss continued to expand, reaching CNY −4.832 billion in 2015, reflecting the increasing pressure on the urban water supply. In short, the dynamic ESV assessment showed that Wuhan had a good ecological environment for the government's policy-making and was paying more and more attention to ecological protection, and the people's willingness to pay for ecosystem services grew continuously.

4.2. Application of ESV in ECC Evaluation

4.2.1. Application of Static ESV in EEC Evaluation

Figure 6 presents the EEC of each district in Wuhan based on static ESV. The EEC of Wuhan calculated based on static ESV was 0.008, −0.008, and −0.038, respectively, in three study stages, corresponding to low-degree coordination, low-degree conflict, and low-degree conflict states. It shows that the ecological and economic development of Wuhan in the study period was basically in a low-degree conflict state, and the economic development was far faster than the growth of ecosystem services value. Especially in the latter two stages, the ecological environment was in a slow retrogression, and people's well-being had declined, which is inconsistent with rapid economic development.

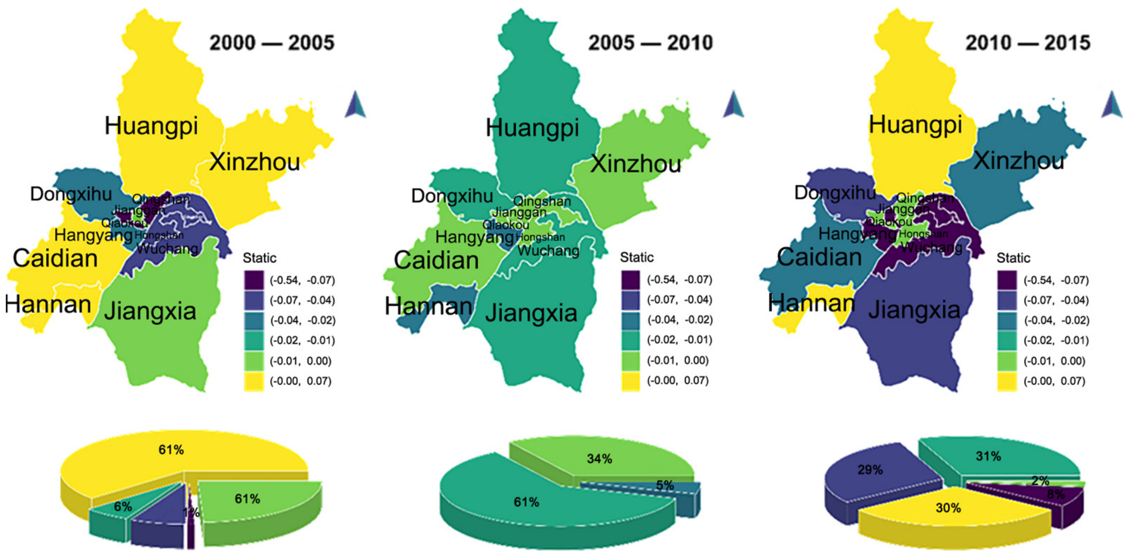

Figure 6. Ecological and economic coordination degree of each district in Wuhan (Static).

The EEC assessment of each district in Wuhan is shown in Figure 5. It can be seen that the EEC values calculated according to the static ESV were basically in the vicinity of zero value, with a negative value in the majority. The maximum value appeared in Caidian District and Huangpi District and the minimum value (−0.54) appeared in Qiaokou District from 2000 to 2005, indicating that the ecological and economic development in all districts of Wuhan except Qiaokou District was basically between low-degree coordination and low-degree conflict. The economic development had a certain impact on the ecological environment, but the conflict was relatively low.

In brief, in the whole study stage, the ecological and economic development of all districts in Wuhan was in a state of low-degree conflict except for Hannan district, indicating that economic development had a certain negative impact on the ecological environment and people's well-being had been damaged to some extent. Nevertheless, the Qingshan District was the least ideal; its EEC was close to the critical point of moderate conflict, so the ecological environment needed to be improved urgently.

4.2.2. Application of Dynamic ESV in EEC Evaluation

Figure 7 presents the EEC of each district in Wuhan based on dynamic ESV. The EEC of Wuhan calculated based on dynamic ESV was −0.0024, 0.0414, and 0.2389, respectively, in the three stages, corresponding to low-degree conflict, low-degree coordination, and low-degree coordination, which is quite different from the estimating results based on static ESV, and the EEC greatly improved, indicating that social development and progress have a positive role in promoting ecological and economic development.

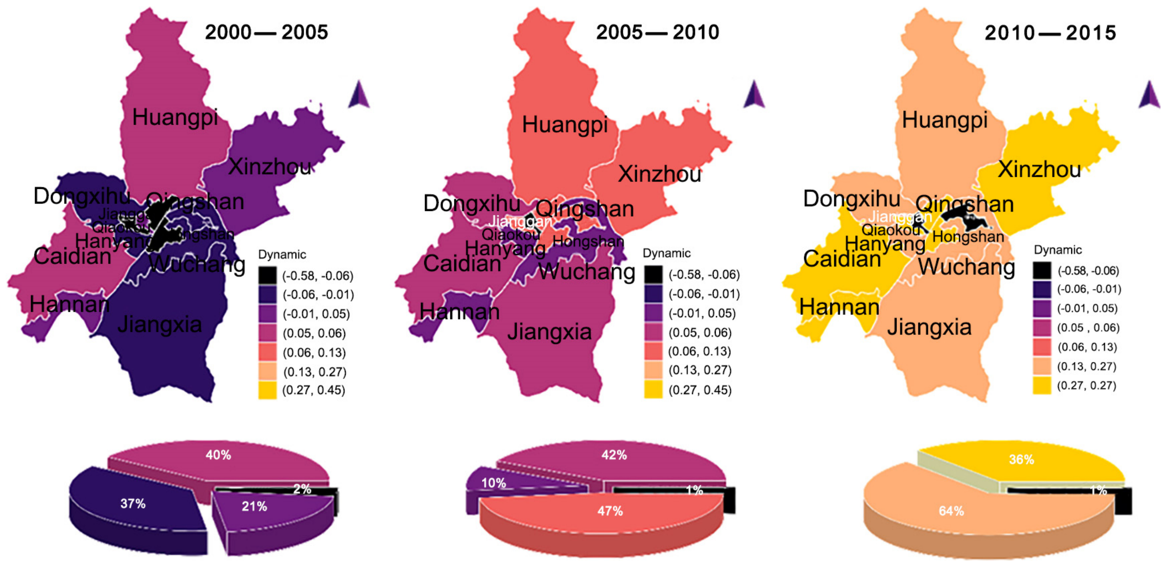

Figure 7. Ecological and economic coordination degree of each district in Wuhan (Dynamic).

The EEC calculated results of different districts are shown in Figure 5. Because the spatial heterogeneity and the impact of changes in willingness to pay on ESV were included in the dynamic ESV evaluation, the variations of ESV in each year were amplified, which makes the EEC differentiation of each region more obvious and is conducive to distinguishing the coordinated development level of each region.

From 2000 to 2005, Caidian District, Huangpi District, Xinzhou District, and Jianghan District were in a low-degree coordination state. Among them, the coordination level of Jianghan District was relatively low, its EEC was only 0.009, while the coordination levels of Caidian District, Huangpi District, and Xinzhou District were in the leading positions in the whole city due to the increase of ESV after dynamic correction and the adjustment of land use structure. The EEC of eight districts such as Dongxihu was between −0.5 and 0, all of which were in a low-degree conflict state. The EEC of the Qiaokou estuary was the lowest in the whole city and was only −0.504, which just falls into the moderate conflict zone; the reason is that many lands were developed and a lot of farmland was transformed into construction land from 2000 to 2005.

From 2005 to 2010, the number of conflict districts dropped from nine to one, and the environmental conditions in these districts improved comprehensively. The level of ecological and economic coordination increased to a certain extent except for a slight decline in Caidian District, among which the four central urban areas of Jiang'an, Qiaokou, Qingshan, and Wuchang showed outstanding performance, and the EEC increased by 0.25, 0.59, 0.17, and 0.15, respectively, thus changing from low-level conflict state to low-level coordination state.

From 2010 to 2015, the EHH of most districts in Wuhan increased significantly. The ecological and economic coordination in Hannan District, Jiang'an District, Wuchang District, and Qiaokou District further rose and approached the moderate coordination level. However, Jianghan District and Qingshan District showed an opposite trend, with EEC dropping rapidly and falling into the moderate conflict zone, indicating that the ecological and economic development of Jianghan District and Qingshan District was not coordinated and there was a risk of further deterioration.

In brief, the EEC assessment results based on dynamic ESV showed a more positive aspect of urban development in Wuhan. This is mainly because the public's willingness to pay for the ecological environment has improved significantly, which has promoted the ecological and economic coordination in most districts of Wuhan.

4.2.3. Comparison of Static and Dynamic ESV in EEC Evaluation

The EEC evaluation results based on static ESV found that the coordination degree of Wuhan and its subordinate districts was decreasing, and there were some conflicts between ecological and economic development. The EEC evaluation results based on dynamic ESV showed that the promotion of social development effectively improved the coordinated development of Wuhan and its subordinate districts.

The application of static ESV in EEC evaluation focuses on the relationship between the value change of ecosystem service function and economic growth. However, the results of ESV assessment showed that the static ESV change was only 4.1% in 15 years, with a GDP change of 803.6 over the same period. The EEC value calculated by this benchmark was very low, most of which were within ± 0.1, and the differences were very small. The EEC value obtained from a few regions was relatively large due to the smaller size of various regions. Dynamic ESV is a correction based on spatial heterogeneity and differences of willingness to pay in different social stages. It is a quantification of the actual utility of ESV in social development and progress. Therefore, the application of dynamic ESV in EEC assessment focuses on the relationship between the actual utility change of ecological services and the growth rate of economic development. Compared with static ESV accounting results, dynamic ESV accounting results can show obvious differences; it made the calculation results of different regions and years show certain hierarchy and diversity. However, the EEC model is calculated by the change of growth rate, and the application of either static ESV or dynamic ESV in EEC evaluation ignores the differences in ESV between districts. For example, in 2000, the static ESV of Jiangxia District was CNY 9.3679 billion, which was 225-times higher than the static ESV of Qiaokou District, which was CNY 41.6 million. Assuming their GDP is the same, if the static ESV of Qiaokou District increases by RMB 4.16 million, it would need to increase by RMB 936 million in Jiangxia District to achieve the same level of ecological and economic coordination as that of Qiaokou District. But, the areas with higher ESV tend to have better ecological environment and relatively backward economic development, which makes coordinated development more difficult. Obviously, it is not appropriate to compare the development of districts horizontally with the EEC calculated in this way.

4.3. Improvement of EEC Evaluation Based on ESV

The correction results of EEC are shown in Figure 8, and the comparison results before and after the correction are shown in Figure 9. After the revision, the EEC of all districts showed an overall upward trend, but the difference between districts became more obvious. Wuchang District, Hannan District, and Jiang'an District significantly improved their coordination degree and entered into the moderate coordination zone, and the coordination development of these districts is the best among all the districts. However, the coordination degree of Qiaokou District has declined due to the small ESV per unit area. In addition, Jianghan District experienced the largest decline, with an EEC of 0.0007, -0.9821, and -6.9627 in the three study periods, which was in a state of high conflict, indicating that the ecological environment deviated from the rapid economic development. The EEC of other regions ranged from 0.49 to 1.95, with a relatively small change after adjustment. Meanwhile, the EEC in these districts was on the rise after adjustment, with a range of 0.49~1.95, reflecting that the ecological and economic development of most districts was coordinated and kept improving. However, the dynamic correction failed to improve the unsustainable development of Jianghan District and Qingshan District, which is mainly related to their small zoning area and construction land occupying a lot of ecological land.

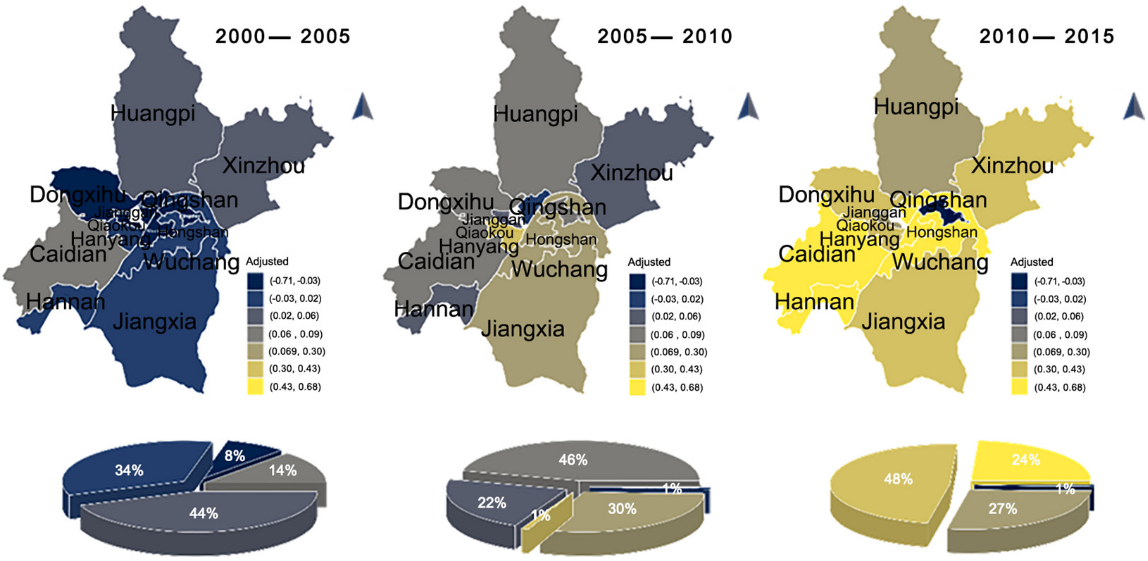

Figure 8. Eco-economic coordination degree of Wuhan Districts (Adjusted).

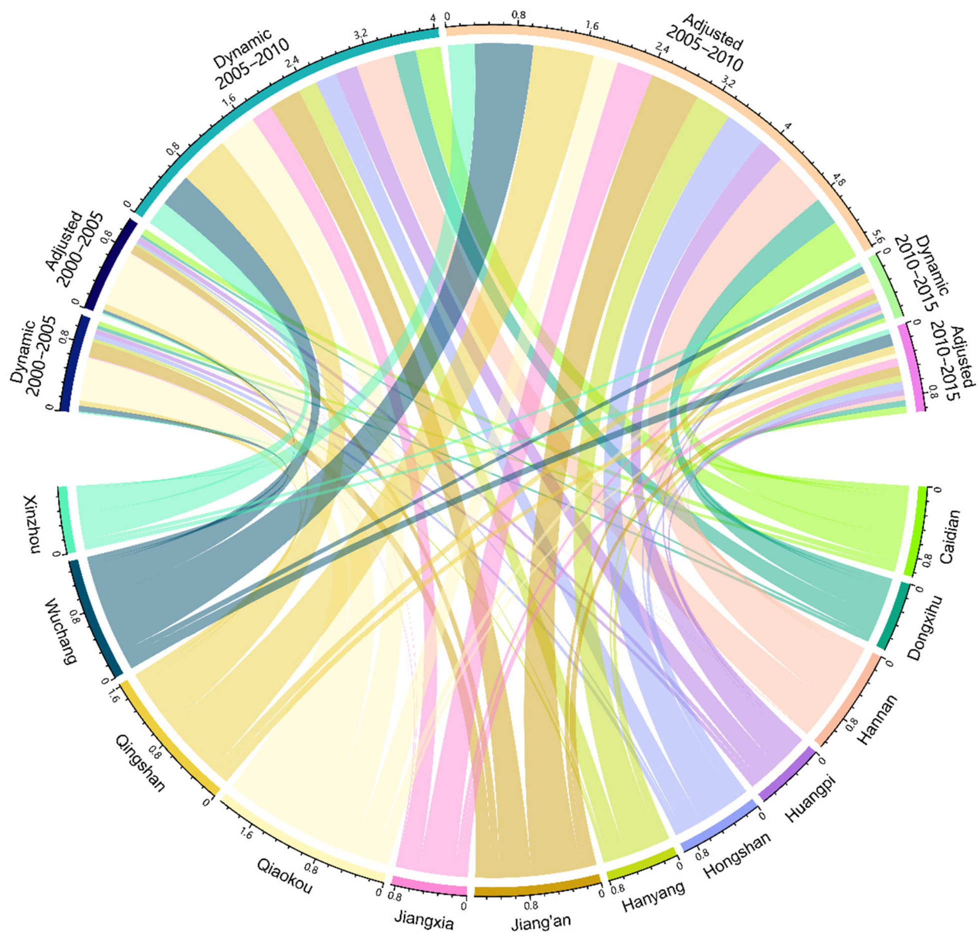

Figure 9. Comparison of eco-economic coordination degree of various districts before and after correction.

5. Discussion

The coordinated development of economy and ecological environment has been recognized as the best choice to deal with the relationship between economic growth and environmental protection, and it is also recognized as the only way to ensure the realization of the strategic goal of sustainable development of human society [71]. The quantitative evaluation of coordination between economic development and ecological environment can provide a relevant theoretical basis for the realization of this goal, which is conducive to, in a timely manner, take effective measures to regulate social and economic activities according to the change of coordination degree to ensure the coordinated development of economic system and natural ecosystem [53]. Because ecosystem services can reflect the interaction, mutual influence, and synergistic evolution of land use and ecosystems, as well as the close interaction between land use and economic development [17], ecosystem services are integrated into the evaluation of eco-economic coordination.

Based on the studies of [21,72], this paper evaluated the static values of different ecosystem services that related to the structure, function, and ecosystem itself, and conducted dynamic ESV evaluation by revising the method of the static ESV evaluation. Afterward, the EEC was estimated by using the static ESV and dynamic ESV, respectively. However, the EEC calculated in this way was not appropriate to compare the development of districts horizontally, even though it is calculated based on static ESV or dynamic ESV [58]. Therefore, to make up for these shortcomings, this paper improved the method of EEC assessment. The method proposed in this paper is helpful to promote the progress in the quantification of eco-economic coordination degree, and the estimated EEC results are more scientific and reliable. Nevertheless, as the economic system and ecosystem are huge and complex systems, their coordination involves the harmonious and consistent development of many aspects [14]. Therefore, the methods on ecological and economic coordinated assessment need further development and improvement to better support sustainable development.

The study discovered that between 2000 and 2015, the static ESV in Wuhan underwent an initial increase followed by a decrease. All ecosystem services, except for hydrological regulation and landscape aesthetic services, exhibited a declining trend. These findings are consistent with the research conducted by [73,74]. The EEC evaluation results based on static ESV found that the coordination degree of Wuhan and its subordinate districts was decreasing, and there were some conflicts between ecological and economic development. Especially in the latter two stages, the ecological environment was in a slow retrogression, and people's well-being had declined, which is inconsistent with rapid economic development. As the static ESV is related to the ecosystem structure and function, the ecological environment needed to be improved urgently especially for the Qingshan District since its EEC was close to the critical point of moderate conflict. In conjunction with the related research by [75,76], it is evident that Wuhan currently faces certain ecological risk issues, and there is a long-term trend of increasing ecological risk. This may be closely related to the lack of coordination between ecological and economic development in Wuhan. The EEC assessment results based on dynamic ESV showed a more positive aspect of urban development in Wuhan. In addition, the EEC assessment of Jianghan District and Qingshan District is still in a moderate conflict zone for a large amount of farmland is occupied by a rapid expansion of urban construction land, which further indicates that the ecological environment of these two districts needs to be improved urgently. We suggest that the disorderly expansion of construction land should be controlled and cultivated land should be used intensively and efficiently.

However, the application of either static ESV or dynamic ESV in EEC evaluation ignores the differences in ESV between districts. Obviously, it is not appropriate to compare the development of districts horizontally with the EEC calculated in this way. Hence, this paper revised the EEC estimation method. The revised EEC estimation showed that the coordination of the ecological and economic development of most districts in Wuhan keeps improving. Nevertheless, it is worth noting that Jianghan District and Qingshan

District are still in unsustainable development, especially for the Jianghan District which experienced the largest decline and presented a state of high conflict. Therefore, we suggest that the improvement of the harmonious development of ecological and economic system in these two districts should be carried out by the adjustment of land use structure and the improvement of environmental quality.

According to the different EEC calculation results, the coordination of ecological and economic development of different districts in Wuhan was compared and analyzed. Accordingly, several relevant policy suggestions can be provided as follows.

(1) Take ecological compensation measures. As the assessment of static ESV revealed a significant loss of ecosystem service value throughout the study period, the government should promptly implement a series of ecological compensation measures. These include adjusting the irrational land use structure, expanding the area of ecological land, and strictly enforcing the farmland protection policy and ecological corridor construction projects, among other ecological protection strategies.
(2) Formulate targeted regional environmental policies. There are significant differences in eco-economic coordination between different areas of Wuhan. Policy formulation should take into account the specific circumstances of each district. For areas where ecological and economic development are highly uncoordinated, such as Qingshan District, special attention should be paid to improving the ecological environment to prevent further loss of ecosystem service values.
(3) Enhance public awareness of ecological protection. The improvement in the dynamic ESV indicates that the public's willingness to pay for ecological services has increased. To further strengthen this trend, it is recommended that a series of favorable policies be introduced to enhance public awareness of ecological protection and promote environmentally friendly consumption behavior. At the same time, relevant departments can improve public understanding of the value of ecosystem services through education and publicity.
(4) Adopt sustainable business strategies and invest in environmentally friendly projects. In order to promote the coordinated development of ecology and economy, enterprises should adopt sustainable business strategies, minimize the improper use of land resources, and improve the efficiency of resource use. Enterprises should expand investment in eco-friendly projects, such as ecological corridor construction and biodiversity protection projects, to promote sustainable development while creating a corporate image with a sense of environmental responsibility.

Although this paper has made a robust and reliable assessment of eco-economic coordination in Wuhan and its districts through the measurement of static and dynamic ESV and the use of an improved EEC model, the current research still has some limitations. First, the monetary valuation of ecosystem service values (ESVs) is influenced by a combination of factors, including inflation rates, value coefficient settings, accuracy of land resource data, and ability of residents to pay. Together, these factors affect the accuracy and reliability of ESV valuations [43,77]. Moreover, due to the complexity of the economic and ecological systems, their coordination involves harmonious development in many aspects [78]. Therefore, assessment methods for eco-economic coordination need to be further developed and refined. Future studies could consider incorporating more complex ecosystem service functions such as biodiversity protection, soil formation, and conservation of construction lands into the scope of research for a deeper level of assessment [70,78]. In addition, ecosystems in different regions exhibit diversity and variability, so the selection of ESV measurement indicators in future research should be more targeted to different geographical areas. Finally, the limitations and timeliness of data collection can lead to discrepancies between assessment results and actual situations. For example, consumption of land resources and changes in the area of different land types may affect the measurement of ESV. Therefore, future research efforts could focus on collecting more up-to-date data on land and resource use to improve the timeliness of assessment results.

6. Conclusions

In this paper, the ecosystem service values were integrated into the estimation of eco-economic coordination degree, and static ESV and dynamic ESV were evaluated, respectively. The traditional EEC evaluation method was improved by introducing the environmental adjustment coefficient. Afterward, the traditional EEC evaluation method and the modified EEC model were, respectively, used to estimate the eco-economic coordination degree, and a comparative analysis was carried out. The relevant conclusions are summarized as follows.

(1) The static ESV assessment showed that the total ESV experienced a loss of CNY 1.24 billion, and the ESV of all ecosystem services showed an increasingly downward trend, except for aesthetic landscape and hydrological regulation. After dynamic revision, the dynamic ESV reversed the overall decreasing trend of the static ESV.
(2) The EEC calculated based on static ESV showed that the ecological and economic development of all districts in Wuhan, except Hannan District, were basically in a low degree of conflict state. However, the EEC calculated based on dynamic ESV has greatly improved.
(3) After the revision, the calculated EEC showed a certain hierarchy and diversity in different districts of Wuhan and the difference in different districts becomes more obvious. The EEC of all districts showed an overall upward trend, reflecting that the ecological and economic development of most districts was coordinated and kept improving. However, the correction EEC failed to improve the unsustainable development of Jianghan District and Qingshan District, especially for Jianghan District which experienced the largest decline and presented in a state of high conflict.

In conclusion (1), the static ESV results showed that Wuhan's ecosystem services are under great pressure. The reversal observed in the dynamic ESV indicates significant changes in social development and a positive shift in public willingness to pay for ecosystem services. In conclusion (2), the EEC calculated from static ESV indicates that economic development has a certain negative impact on the ecological environment and people's well-being has been damaged to some extent. This may be related to the rapid urbanization process. For example, the massive expansion of construction land has led to a significant increase in water consumption for industrial and residential purposes, resulting in a substantial burden on the water supply. Conversely, the EEC derived from dynamic ESV reflects improved coordination between ecological and economic development. This is mainly because the public's willingness to pay for the ecological environment has improved significantly, which has promoted ecological and economic coordination in most districts of Wuhan. In conclusion (3), the revised EEC reveals significant eco-economic discoordination issues in Wuhan's Jianghan District and Qingshan District, which may be closely related to their small administrative area and the extensive occupation of ecological land by construction land.

These findings imply that although the ecological environment of Wuhan is improved to a certain extent, the coordination of economic growth and ecological conservation still bears great downward pressure and needs further improvement.

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References

1. National Bureau of Statistics of China. China Statistical Yearbook 2020. 2020. Available online: https://www.stats.gov.cn/sj/ndsj/2020/indexch.htm (accessed on 2 February 2024).
2. Chen, W.; Zhao, H.; Li, J.; Zhu, L.; Wang, Z.; Zeng, J. Land use transitions and the associated impacts on ecosystem services in the Middle Reaches of the Yangtze River Economic Belt in China based on the geo-informatic Tupu method. *Sci. Total. Environ.* **2020**, *701*, 134690. [CrossRef] [PubMed]
3. Xing, L.; Xue, M.; Wang, X. Spatial correction of ecosystem service value and the evaluation of eco-efficiency: A case for China's provincial level. *Ecol. Indic.* **2018**, *95 Pt 1*, 841–850. [CrossRef]
4. Cui, X.; Fang, C.; Liu, H.; Liu, X. Assessing sustainability of urbanization by a coordinated development index for an Urbanization-Resources-Environment complex system: A case study of Jing-Jin-Ji region, China. *Ecol. Indic.* **2019**, *96*, 383–391. [CrossRef]
5. Chen, M.; Liu, W.; Lu, D. Challenges and the way forward in China's new-type urbanization. *Land Use Policy* **2016**, *55*, 334–339. [CrossRef]
6. Cao, W.; Li, R.; Chi, X.; Chen, N.; Chen, J.; Zhang, H.; Zhang, F. Island urbanization and its ecological consequences: A case study in the Zhoushan Island, East China. *Ecol. Indic.* **2017**, *76*, 1–14. [CrossRef]
7. Kindu, M.; Schneider, T.; Teketay, D.; Knoke, T. Changes of ecosystem service values in response to land use/land cover dynamics in Munessa–Shashemene landscape of the Ethiopian highlands. *Sci. Total. Environ.* **2016**, *547*, 137–147. [CrossRef] [PubMed]
8. Hernández-Blanco, M.; Costanza, R.; Anderson, S.; Kubiszewski, I.; Sutton, P. Future scenarios for the value of ecosystem services in Latin America and the Caribbean to 2050. *Curr. Res. Environ. Sustain.* **2020**, *2*, 100008. [CrossRef]
9. Fei, L.; Shuwen, Z.; Jiuchun, Y.; Liping, C.; Haijuan, Y.; Kun, B. Effects of land use change on ecosystem services value in West Jilin since the reform and opening of China. *Ecosyst. Serv.* **2018**, *31*, 12–20. [CrossRef]
10. Ongsomwang, S.; Pattanakiat, S.; Srisuwan, A. Impact of Land Use and Land Cover Change on Ecosystem Service Values: A Case Study of Khon Kaen City, Thailand. *Environ. Nat. Resour. J.* **2019**, *17*, 43–58. [CrossRef]
11. Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W.; Tolessa, T.; Kindu, M. Estimating the impacts of land use/land cover changes on ecosystem service values: The case of the andassa watershed in the upper blue nile basin of Ethiopia. *Ecosyst. Serv.* **2018**, *31 Pt A*, 219–228. [CrossRef]
12. Sannigrahi, S.; Bhatt, S.; Rahmat, S.; Paul, S.K.; Sen, S. Estimating global ecosystem service values and its response to land surface dynamics during 1995–2015. *J. Environ. Manag.* **2018**, *223*, 115–131. [CrossRef]
13. Dogan, E.; Majeed, M.T.; Luni, T. Revisiting the nexus of ecological footprint, unemployment, and renewable and non-renewable energy for South Asian economies: Evidence from novel research methods. *Renew. Energy* **2022**, *194*, 1060–1070. [CrossRef]
14. Li, Y.; Li, Z.; Wang, J.; Zeng, H. Analyses of driving factors on the spatial variations in regional eco-environmental quality using two types of species distribution models: A case study of Minjiang River Basin, China. *Ecol. Indic.* **2022**, *139*, 108980. [CrossRef]
15. Chen, D.; Lu, X.; Hu, W.; Zhang, C.; Lin, Y. How urban sprawl influences eco-environmental quality: Empirical research in China by using the Spatial Durbin model. *Ecol. Indic.* **2021**, *131*, 108113. [CrossRef]
16. Chen, W.; Chi, G.; Li, J. The spatial association of ecosystem services with land use and land cover change at the county level in China, 1995–2015. *Sci. Total. Environ.* **2019**, *669*, 459–470. [CrossRef]
17. Song, W.; Deng, X. Land-use/land-cover change and ecosystem service provision in China. *Sci. Total. Environ.* **2017**, *576*, 705–719. [CrossRef] [PubMed]
18. Marques, A.; Martins, I.S.; Kastner, T.; Plutzar, C.; Theurl, M.C.; Eisenmenger, N.; Huijbregts, M.A.J.; Wood, R.; Stadler, K.; Bruckner, M.; et al. Increasing impacts of land use on biodiversity and carbon sequestration driven by population and economic growth. *Nat. Ecol. Evol.* **2019**, *3*, 628–637. [CrossRef] [PubMed]
19. De Groot, R.S.; Wilson, M.A.; Boumans, R.M.J. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecol. Econ.* **2002**, *41*, 393–408. [CrossRef]
20. Cheng, X.; Xu, Z.; Yu, S.; Peng, J. A wavelet coherence approach to detecting ecosystem services trade-off response to land use change. *J. Environ. Manag.* **2022**, *316*, 115160. [CrossRef]
21. Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
22. Millennium Ecosystem Assessment (MEA). *Ecosystems and Human Well-Being*; Island Press: Washington, DC, USA, 2005.
23. SCEP. *Man's Impact on the Global Environment: Study of Critical Environmental Problems*; MIT Press: Cambridge, MA, USA, 1970.
24. Pascual, U.; Balvanera, P.; Díaz, S.; Pataki, G.; Roth, E.; Stenseke, M.; Watson, R.T.; Dessane, E.B.; Islar, M.; Kelemen, E.; et al. Valuing nature's contributions to people: The IPBES approach. *Curr. Opin. Environ. Sustain.* **2017**, *26–27*, 7–16. [CrossRef]

25. Haines-Young, R.; Potschin-Young, M. *Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting*; Report to the European Environment Agency; Department of Economic and Social Affairs, Statistics Division, United Nations: New York, NY, USA, 2010.
26. Daily, G.C.; Söderqvist, T.; Aniyar, S.; Arrow, K.; Dasgupta, P.; Ehrlich, P.R.; Folke, C.; Jansson, A.; Jansson, B.-O.; Kautsky, N.; et al. The Value of Nature and the Nature of Value. *Science* **2000**, *289*, 395–396. [CrossRef] [PubMed]
27. Wainger, L.A.; King, D.M.; Mack, R.N.; Price, E.W.; Maslin, T. Can the concept of ecosystem services be practically applied to improve natural resource management decisions? *Ecol. Econ.* **2010**, *69*, 978–987. [CrossRef]
28. Xie, G.; Zhang, C.; Zhen, L.; Zhang, L. Dynamic changes in the value of China's ecosystem services. *Ecosyst. Serv.* **2017**, *26*, 146–154. [CrossRef]
29. Xie, G.D.; Lu, C.X.; Leng, Y.F.; Zheng, D.; Cheng, L.S. Ecological assets valuation of the Tibetan Plateau. *J. Nat. Resour.* **2003**, *18*, 189–196.
30. State Forestry Administration of the People's Republic of China. Specifications for Assessment of Forest Ecosystem Service Function (LY/T1721–2008). 2008. Available online: http://www.forestry.gov.cn/portal/hdy/s/1510/content-132624.html (accessed on 15 September 2010). (In Chinese)
31. Li, H.; Huang, Y.; Zhou, Y.; Wang, S.; Guo, W.; Liu, Y.; Wang, J.; Xu, Q.; Zhou, X.; Yi, K.; et al. Spatial and Temporal Evolution of Ecosystem Service Values and Topography-Driven Effects Based on Land Use Change: A Case Study of the Guangdong–Hong Kong–Macao Greater Bay Area. *Sustainability* **2023**, *15*, 9691. [CrossRef]
32. Zhang, B.; Li, L. Evaluation of ecosystem service value and vulnerability analysis of China national nature reserves: A case study of Shennongjia Forest Region. *Ecol. Indic.* **2023**, *149*, 110188. [CrossRef]
33. Petroni, M.L.; Siqueira-Gay, J.; Gallardo, A.L.C.F. Understanding land use change impacts on ecosystem services within urban protected areas. *Landsc. Urban Plan.* **2022**, *223*, 104404. [CrossRef]
34. Daily, G.C. Nature's Services: Societal Dependence on Natural Ecosystems. In *The Future of Nature: Documents of Global Change*; Robin, L., Sörlin, S., Warde, P., Eds.; Yale University Press: New Haven, CT, USA, 2013; pp. 454–464. [CrossRef]
35. Kreuter, U.P.; Harris, H.G.; Matlock, M.D.; Lacey, R.E. Change in ecosystem service values in the San Antonio area, Texas. *Ecol. Econ.* **2001**, *39*, 333–346. [CrossRef]
36. Ahern, J.; Cilliers, S.; Niemelä, J. The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landsc. Urban Plan.* **2014**, *125*, 254–259. [CrossRef]
37. Estoque, R.C.; Murayama, Y. Landscape pattern and ecosystem service value changes: Implications for environmental sustainability planning for the rapidly urbanizing summer capital of the Philippines. *Landsc. Urban Plan.* **2013**, *116*, 60–72. [CrossRef]
38. Hu, M.; Li, Z.; Wang, Y.; Jiao, M.; Li, M.; Xia, B. Spatio-temporal changes in ecosystem service value in response to land-use/cover changes in the Pearl River Delta. *Resour. Conserv. Recycl.* **2019**, *149*, 106–111. [CrossRef]
39. Costanza, R.; de Groot, R.; Sutton, P.; van der Ploeg, S.; Anderson, S.J.; Kubiszewski, I.; Farber, S.; Turner, R.K. Changes in the global value of ecosystem services. *Glob. Environ. Change* **2014**, *26*, 152–158. [CrossRef]
40. Kareiva, P.; Tallis, H.; Ricketts, T.H.; Daily, G.C.; Polasky, S. (Eds.) *Natural Capital: Theory and Practice of Mapping Ecosystem Services*; Oxford Academic: Oxford, UK, 2011. Available online: https://doi.org/10.1093/acprof:oso/9780199588992.001.0001 (accessed on 19 December 2023).
41. Moisa, M.B.; Negash, D.A.; Merga, B.B.; Gemeda, D.O. Impact of land-use and land-cover change on soil erosion using the RUSLE model and the geographic information system: A case of Temeji watershed, Western Ethiopia. *J. Water Clim. Chang.* **2021**, *12*, 3404–3420. [CrossRef]
42. Noojipady, P. Land Use and Land Cover Change as a Driver of Ecosystem Degradation across Biomes. 2016. Available online: https://api.semanticscholar.org/CorpusID:134126872 (accessed on 2 February 2024).
43. Li, Y.; Zhan, J.; Liu, Y.; Zhang, F.; Zhang, M. Response of ecosystem services to land use and cover change: A case study in Chengdu City. *Resour. Conserv. Recycl.* **2018**, *132*, 291–300. [CrossRef]
44. Li, B.; Chen, D.; Wu, S.; Zhou, S.; Wang, T.; Chen, H. Spatio-temporal assessment of urbanization impacts on ecosystem services: Case study of Nanjing City, China. *Ecol. Indic.* **2016**, *71*, 416–427. [CrossRef]
45. Qiu, B.; Li, H.; Zhou, M.; Zhang, L. Vulnerability of ecosystem services provisioning to urbanization: A case of China. *Ecol. Indic.* **2015**, *57*, 505–513. [CrossRef]
46. Peng, J.; Liu, Y.; Wu, J.; Lv, H.; Hu, X. Linking ecosystem services and landscape patterns to assess urban ecosystem health: A case study in Shenzhen City, China. *Landsc. Urban Plan.* **2015**, *143*, 56–68. [CrossRef]
47. Sonter, L.J.; Johnson, J.A.; Nicholson, C.C.; Richardson, L.L.; Watson, K.B.; Ricketts, T.H. Multi-site interactions: Understanding the offsite impacts of land use change on the use and supply of ecosystem services. *Ecosyst. Serv.* **2017**, *23*, 158–164. [CrossRef]
48. Wu, W.; Wang, W.; Zhang, M. Using China's provincial panel data exploring the interaction between Socio-economic and Eco-environment system. *Ecol. Complex.* **2020**, *44*, 100873. [CrossRef]
49. Zhang, W.; Zhang, M.; Wu, S.; Liu, F. A complex path model for low-carbon sustainable development of enterprise based on system dynamics. *J. Clean. Prod.* **2021**, *321*, 128934. [CrossRef]
50. Yang, Y.; Lu, H.; Liang, D.; Chen, Y.; Tian, P.; Xia, J.; Wang, H.; Lei, X. Ecological sustainability and its driving factor of urban agglomerations in the Yangtze River Economic Belt based on three-dimensional ecological footprint analysis. *J. Clean. Prod.* **2022**, *330*, 129802. [CrossRef]

51. Ali, Q.; Yaseen, M.R.; Anwar, S.; Makhdum, M.S.A.; Khan, M.T.I. The impact of tourism, renewable energy, and economic growth on ecological footprint and natural resources: A panel data analysis. *Resour. Policy* **2021**, *74*, 102365. [CrossRef]
52. Li, W.; Yi, P.; Zhang, D.; Zhou, Y. Assessment of coordinated development between social economy and ecological environment: Case study of resource-based cities in Northeastern China. *Sustain. Cities Soc.* **2020**, *59*, 102208. [CrossRef]
53. Fan, Y.; Fang, C.; Zhang, Q. Coupling coordinated development between social economy and ecological environment in Chinese provincial capital cities-assessment and policy implications. *J. Clean. Prod.* **2019**, *229*, 289–298. [CrossRef]
54. Wu, J.; Li, B.; Zhang, X. Ecosystem service value and its aplication in evaluation of eco-economic harmonious development. *Ying Yong Sheng Tai Xue Bao = J. Appl. Ecol.* **2007**, *18*, 2554–2558.
55. Liu, J.; Pei, X.; Zhu, W.; Jiao, J. Simulation of the Ecological Service Value and Ecological Compensation in Arid Area: A Case Study of Ecologically Vulnerable Oasis. *Remote Sens.* **2023**, *15*, 3927. [CrossRef]
56. Riao, D.; Zhu, X.; Tong, Z.; Zhang, J.; Wang, A. Study on Land Use/Cover Change and Ecosystem Services in Harbin, China. *Sustainability* **2020**, *12*, 6076. [CrossRef]
57. Tao, Y.; Wang, H.; Ou, W.; Guo, J. A land-cover-based approach to assessing ecosystem services supply and demand dynamics in the rapidly urbanizing Yangtze River Delta region. *Land Use Policy* **2018**, *72*, 250–258. [CrossRef]
58. Ma, S.; Huang, Z. Quantitative Evaluation of Coordinated Development between Ecological and Economic Systems in a Coal-Intensive City in China. *J. Urban Plan. Dev.* **2021**, *147*, 04021051. [CrossRef]
59. Resource and Environment Science Data Center of Chinese Academy of Sciences. Available online: http://www.resdc.cn (accessed on 8 January 2023).
60. Wuhan Municipal Ecology and Environment Bureau. Available online: http://hbj.wuhan.gov.cn (accessed on 10 January 2023).
61. Wang, R.C.; Ban, Y.; Guo, X.T. Ecological Service Evaluation Model Based on Equivalent Factor Method. In Proceedings of the 2020 International Conference on Social and Human Sciences (ICSHS2020), Canberra, Australia, 7–8 March 2020.
62. Cui, X.; Liu, C.; Shan, L.; Lin, J.; Zhang, J.; Jiang, Y.; Zhang, G. Spatial-Temporal Responses of Ecosystem Services to Land Use Transformation Driven by Rapid Urbanization: A Case Study of Hubei Province, China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 178. [CrossRef] [PubMed]
63. Ye, Y.; Bryan, B.A.; Zhang, J.; Connor, J.D.; Chen, L.; Qin, Z.; He, M. Changes in land-use and ecosystem services in the Guangzhou-Foshan Metropolitan Area, China from 1990 to 2010: Implications for sustainability under rapid urbanization. *Ecol. Indic.* **2018**, *93*, 930–941. [CrossRef]
64. Weng, C.; Bai, Y.; Chen, B.; Hu, Y.; Liu, S.; Wu, L. Virtual built-up land transfers and induced ecosystem service potential loss embodied in China's inter-regional trade. *Land Degrad. Dev.* **2023**, *35*, 597–607. [CrossRef]
65. Xie, G.; Cao, S.; Xiao, Y.; Pei, X.; Bai, Y.; Li, W.; Wang, B.; Niu, X.; Liu, X.; Xu, Z.; et al. Ecosystem Service Evaluation. In *Contemporary Ecology Research in China*; Li, W., Ed.; Springer: Berlin/Heidelberg, Germany, 2015; Chapter 7. [CrossRef]
66. Wan, L.; Ye, X.; Lee, J.; Lu, X.; Zheng, L.; Wu, K. Effects of urbanization on ecosystem service values in a mineral resource-based city. *Habitat Int.* **2015**, *46*, 54–63. [CrossRef]
67. Xue, M.; Luo, Y. Dynamic variations in ecosystem service value and sustainability of urban system: A case study for Tianjin city, China. *Cities* **2015**, *46*, 85–93. [CrossRef]
68. Zang, Z.; Zou, X.; Zuo, P.; Song, Q.; Wang, C.; Wang, J. Impact of landscape patterns on ecological vulnerability and ecosystem service values: An empirical analysis of Yancheng Nature Reserve in China. *Ecol. Indic.* **2017**, *72*, 142–152. [CrossRef]
69. Sannigrahi, S.; Chakraborti, S.; Joshi, P.K.; Keesstra, S.; Sen, S.; Paul, S.K.; Kreuter, U.P.; Sutton, P.C.; Jha, S.; Dang, K.B. Ecosystem service value assessment of a natural reserve region for strengthening protection and conservation. *J. Environ. Manag.* **2019**, *244*, 208–227. [CrossRef]
70. Ma, S.; Wang, L.; Ji, S.; Xing, L. Assessing the dynamic variations of ecosystem service value in response to land use change and socio-economic development. *J. Environ. Plan. Manag.* **2022**, *65*, 2511–2537. [CrossRef]
71. Liu, W.; Zhan, J.; Zhao, F.; Yan, H.; Zhang, F.; Wei, X. Impacts of urbanization-induced land-use changes on ecosystem services: A case study of the Pearl River Delta Metropolitan Region, China. *Ecol. Indic.* **2019**, *98*, 228–238. [CrossRef]
72. Xie, G.D.; Zhen, L.; Lu, C.X.; Xiao, Y.; Chen, C. Expert knowledge based valuation method of ecosystem services in China. *J. Nat. Resour.* **2008**, *23*, 911–919.
73. Zhang, Y.; Zheng, M.; Qin, B. Optimization of spatial layout based on ESV-FLUS model from the perspective of "Production-Living-Ecological": A case study of Wuhan City. *Ecol. Model.* **2023**, *481*, 110356. [CrossRef]
74. Zhang, X.; Ren, W.; Peng, H. Urban land use change simulation and spatial responses of ecosystem service value under multiple scenarios: A case study of Wuhan, China. *Ecol. Indic.* **2022**, *144*, 109526. [CrossRef]
75. Zhang, Z.; Gong, J.; Plaza, A.; Yang, J.; Li, J.; Tao, X.; Wu, Z.; Li, S. Long-term assessment of ecological risk dynamics in Wuhan, China: Multi-perspective spatiotemporal variation analysis. *Environ. Impact Assess. Rev.* **2024**, *105*, 107372. [CrossRef]
76. Peng, Y.; Cheng, W.; Xu, X.; Song, H. Analysis and prediction of the spatiotemporal characteristics of land-use ecological risk and carbon storage in Wuhan metropolitan area. *Ecol. Indic.* **2024**, *158*, 111432. [CrossRef]

77. Su, K.; Wei, D.-Z.; Lin, W.-X. Evaluation of ecosystem services value and its implications for policy making in China—A case study of Fujian province. *Ecol. Indic.* **2020**, *108*, 105752. [CrossRef]
78. Peng, W.F.; Zhou, J.M.; Fan, S.Y.; Yang, C.J. Effects of the Land Use Change on Ecosystem Service Value in Chengdu, Western China from 1978 to 2010. *J. Indian Soc. Remote. Sens.* **2016**, *44*, 197–206. [CrossRef]