sustainability

MDPI

Article

A Study of the Spatiotemporal Evolution Patterns and Coupling Coordination between Ecosystem Service Values and Habitat Quality in Diverse Scenarios: The Case of Chengdu Metropolitan Area, China

Gaoliu Huang [1,2,3], Shiming Feng [1,*] and Chunguang Hu [2,3]

[1] Department of History, School of Social Sciences, Soochow University, Suzhou 215123, China; huanggaoliu@hust.edu.cn
[2] School of Architecture and Urban Planning, Huazhong University of Science and Technology, Wuhan 430074, China; huchunguang@hust.edu.cn
[3] Hubei Engineering and Technology Research Center of Urbanization, Wuhan 430074, China
* Correspondence: fengshiming@suda.edu.cn

Abstract: The global ecological decline resulting from urban development presents a significant challenge for numerous regions striving to reconcile conservation efforts with developmental needs. This study explores the relationship between ecosystem service value (ESV) and habitat quality (HQ) under various scenarios to elucidate prospective development trajectories. This study utilized the PLUS model to simulate land use patterns in the Chengdu metropolitan area across four distinct development scenarios. Furthermore, it employed the equivalent factor method and the Invest model to quantify ESV and HQ values, and investigated the coupling coordination between ESV and HQ for each city using a coupling coordination model (CCM). The findings are as follows: (1) Between 2000 and 2020, land use in the Chengdu metropolitan area primarily expanded through the development of construction land. (2) Concurrently, ESV demonstrated a fluctuating trend characterized by an initial decline succeeded by an upsurge, culminating under the Development–Ecological Balance Scenario. Likewise, HQ displayed a similar fluctuating pattern with an initial decline succeeded by an increase, reaching its zenith under the Ecological Dominance Scenario. (3) The coupling coordination between ESV and HQ exhibited variability across cities and scenarios. Ultimately, this study offers a distinctive perspective on evaluating the interplay between urban development and conservation, providing valuable insights for promoting sustainable development in other regions.

Keywords: ecosystem service value (ESV); habitat quality (HQ); land use simulation; coupling coordination model (CCM); Chengdu metropolitan area

Citation: Huang, G.; Feng, S.; Hu, C. A Study of the Spatiotemporal Evolution Patterns and Coupling Coordination between Ecosystem Service Values and Habitat Quality in Diverse Scenarios: The Case of Chengdu Metropolitan Area, China. *Sustainability* **2024**, *16*, 3741. https://doi.org/10.3390/su16093741

Academic Editors: Zhe Feng and Huafu Zhao

Received: 1 April 2024
Revised: 25 April 2024
Accepted: 25 April 2024
Published: 29 April 2024

1. Introduction

The global ecological balance between environmental preservation and economic growth has increasingly become a paramount concern for nations worldwide. The 2023 Global Sustainable Development Report (GSDR), published by the United Nations, emphasizes the imperative of aligning future development with sustainable practices, integrating environmental preservation with economic progress [1]. Numerous studies have demonstrated the escalating harm inflicted on ecosystems by human activities. Amidst ongoing economic expansion and land development, ecosystem diversity continues to decline [2]. Consequently, achieving a balance between protection and development has emerged as a pivotal challenge in regional studies [3]. Since the adoption of China's reform and opening-up policy, the nation's economy has exhibited traits of constrained growth, indicative of a government-led "growth-oriented" development paradigm. Consequently, it progressively encroaches upon ecological habitats, significantly impacting the environment. Thus, it is imperative to chart a viable course for urban development to foster the sustainable growth of cities.

Ecosystem services encompass the direct and indirect benefits humans derive from ecosystems that are crucial for their sustenance and development. Ecosystem Services Value (ESV) serves as an indicator for quantifying the value derived from ecosystem services [4]. Analyzing changes in ESV characteristics reveals the benefits ecosystems bestow upon humanity, pivotal in understanding regional ecosystem values and fostering regional sustainable development. The ESV is the value that can be directly or indirectly obtained from ecosystems and utilized by humans. Various methods have been proposed by scholars for ESV estimation, encompassing the direct market method [5], the hypothetical market value method [6], the substitution market method [7], the energy value analysis method [8], and the equivalent factor method [9]. Among them, the equivalent factor method has been widely used due to its comprehensive assessment scope and simplicity of operation. However, the equivalent factor method is based on the value equivalent of various service functions of different types of ecosystems, combined with the area of the ecosystem for calculation and evaluation. It does not fully reflect the actual situation in different regions in terms of defining the value equivalent. Building upon Costanza et al.'s research, Chinese scholars have introduced the concept of "Equivalent ecosystem services value per Unit Area of Chinese Terrestrial Ecosystems [10,11]". Consequently, the equivalent factor method finds extensive utility in ESV estimation. Many scholars have conducted in-depth analysis of ESV under land use change (LUC) based on this method. Nevertheless, these studies predominantly investigate the spatiotemporal dynamics and interactions between ESV and LUC at provincial [12,13], basin [14], and nature reserve scales [15]. While these studies offer a theoretical foundation for devising regional management strategies, they inadequately address the complexities of metropolitan areas, a spatial unit of greater intricacy [16]. Secondly, in terms of research content, some scholars have explored ecological risk assessment [17], scale effect assessment [18], ecological security patterns [19], and related topics rooted in regional ESV exploration, offering diverse measures and recommendations for ecological preservation and management.

Habitat Quality (HQ) frequently serves as a metric for assessing biodiversity levels within specific regions. HQ reflects the vitality of the local ecosystem and constitutes a crucial criterion for evaluating ecosystem sustainability. Methods for calculating HQ primarily comprise ecological surveys, evaluation indices, and model-based computations. Ecological survey methods gather data through field surveys, but their high costs render them impractical for large-scale research. The evaluation index method assesses HQ via predetermined indicators, yet its operational complexity and lack of regional universality pose limitations. Model-based computations, in contrast, offer greater scientific rigor, with open-source software such as Invest streamlining operational procedures. The Invest model accurately computes results and facilitates visualization, rendering it a popular choice for HQ assessment in various regions. Consequently, the Invest model has seen widespread application in elucidating the spatiotemporal dynamics of HQ and its influencing factors. Presently, research predominantly concentrates on individual ecological reserves [20], urban units [21], and provincial scales [22]. Nonetheless, there exists a relative dearth of comprehensive investigations concerning large-scale, composite spatial entities like metropolitan areas. Furthermore, while tools like geographically weighted regression [23], geographic detectors [24], and PLUS have been used to analyze the changes in HQ and their driving forces, there are also many scholars who combine PLUS and other land use simulation software to explore the characteristics of HQ changes under multiple scenarios [25,26].

Nonetheless, within the current research domain, there remains a dearth of exploration regarding the interaction mechanisms and relationships between ESV and HQ [27,28]. Numerous studies often analyze these aspects in isolation, employing methodologies such as land use change models and the Invest model to assess ecological risks in urban and nature reserve areas [29,30], or investigating the repercussions of urban land use change on

ESV [31]. Serving as pivotal metrics for evaluating ecosystem health comprehensively, ESV and HQ offer quantitative insights into ecosystem development trends and human habitation quality, elucidating economic and qualitative aspects with considerable explanatory power. Nevertheless, as society progresses, striking a balance between urban expansion and environmental preservation has emerged as a critical concern in urban development planning and enhancing human living conditions. Nonetheless, investigations into the interaction and significance of ESV and HQ in future urban planning and environmental management remain sparse, let alone in-depth analyses of their coupling and coordination mechanisms amidst environmental changes.

Previous research readily reveals that both ESV and HQ assessments necessitate land use as an evaluation medium, suggesting a reciprocal relationship wherein they mutually influence each other. Presently, numerous researchers concentrate on the correlation between land use change and ecosystems, recognizing that land use and its alterations are pivotal factors driving ESV and HQ fluctuations [32]. Land use changes exert direct effects on HQ [33,34], either enhancing or degrading it, consequently influencing species diversity indirectly [26,35,36]. Furthermore, land use change can modify ecosystems' capacity to furnish ESV [12,37], consequently shaping the spatiotemporal attributes of HQ [38–41]. Hence, optimizing HQ and ESV through land use change simulation holds both theoretical underpinning and practical significance [42]. Various land use models have been developed, encompassing the CLUE-S model [43], cellular automaton (CA) [44], FLUS model [45], and PLUS model [16]. The PLUS model integrates cutting-edge analytical techniques and distinctive multi-type seed growth algorithms, facilitating a more nuanced examination of dynamic LUC and surpassing the constraints of conventional models in simulation accuracy and mechanistic explanation [16].

Concurrently, owing to the swift urban construction progress in China, metropolitan areas have emerged as crucial pillars for the nation's new urbanization endeavors [46]. Additionally, the Chinese government has implemented pertinent policies to bolster metropolitan area development. Numerous studies have illustrated that, over the past two decades, while cities within the Chengdu metropolitan area have undergone rapid economic growth and land expansion, their ecological environment quality has steadily deteriorated [47,48]. Nevertheless, indiscriminate economic development control may impede societal progress and advancement. Thus, the challenge for future Chengdu metropolitan area development lies in effectively coordinating and balancing economic development with ecological preservation. The stringent protections on cropland preservation boundaries during the Chengdu metropolitan area's development signify not only the keen focus on safeguarding agricultural land but also offer a distinctive lens for investigating the intricate ESV–HQ relationship in the region. Cropland serves not only as the cornerstone of food production but also plays an indispensable role in supplying material resources, regulating climate, and preserving biodiversity. Nevertheless, certain studies have highlighted the imperative to acknowledge the adverse effects of cropland expansion and utilization on HQ, rendering the Chengdu metropolitan area an optimal study site for investigating the ESV–HQ relationship through land use change analysis.

Hence, this study concentrates on the spatial dimensions of the Chengdu metropolitan area. It comprehensively assesses the spatiotemporal evolution of ESV, employing the "Equivalent Value of Ecosystem Services per Unit Area of Chinese Terrestrial Ecosystems" alongside its distinct urban environmental features. Moreover, it precisely computes the HQ of the metropolitan area by integrating the PLUS model and the Invest model, endeavoring to portray the holistic health condition of the regional ecosystem on a macroscopic level. Furthermore, it examines the spatiotemporal aspects of the ecological environment quality of the metropolitan area from an economic standpoint, seeking to elucidate the coupling and coordination mechanisms between ESV and HQ. This study endeavors to furnish a scientific foundation for decision-making concerning the ecological protection and management of metropolitan areas, holding significant theoretical and practical implications for fostering the harmonious coexistence of ecosystems and human activities.

2. Materials and Methods

2.1. Geographic Area of Investigation

The study area chosen for this research is the Chengdu metropolitan area. The Chengdu metropolitan area, located in the southwestern part of China, is a key area for economic development and is known for its strong economic capabilities and abundant ecological resources [49,50]. From a geographical perspective, the Chengdu metropolitan area is situated in the eastern part of Sichuan Province, China. It primarily comprises cities and counties such as Chengdu, Deyang, Ziyang, and Meishan. The total area covers 33,100 square kilometers (Figure 1).

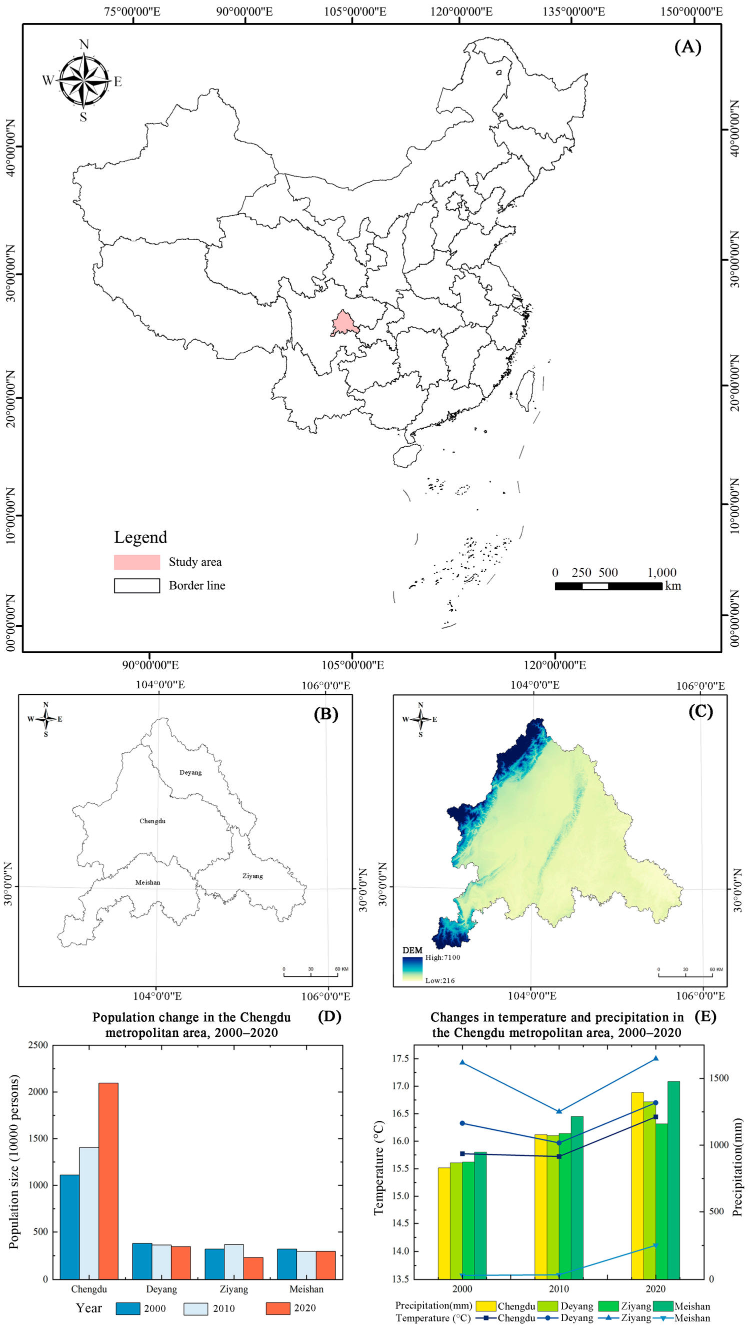

Figure 1. Geographic area of investigation. (**A**) Location of the study area in the country. (**B**) Administrative division of the study area. (**C**) Elevation of the study area. (**D**) Population changes in the study area from 2000 to 2020. (**E**) Temperature and precipitation in the study area from 2000 to 2020.

2.2. Research Structure

This study examined the LUC in the Chengdu metropolitan area over the years. It utilized natural geographic data and socio-economic data, combined with the PLUS model, to simulate LUC in the Chengdu metropolitan area under four different scenarios. Additionally, it employed the equivalent factor method in conjunction with statistical yearbook data to calculate changes in the ESV over the years in the Chengdu metropolitan area. The Invest model was also used to investigate the spatiotemporal variations in HQ in the Chengdu metropolitan area. Furthermore, by integrating the results of ESV and HQ calculations, a coupling coordination model (CCM) was applied to explore the coupling and coordination relationships between ESV and HQ across different areas within the Chengdu metropolitan area. Finally, based on the research findings, this study delved into the spatiotemporal characteristics of ESV and HQ, as well as their coupling coordination (CC) relationships in the Chengdu metropolitan area. It also discussed potential urban development model paths based on the outcomes of the multifaceted scenario simulations (Figure 2).

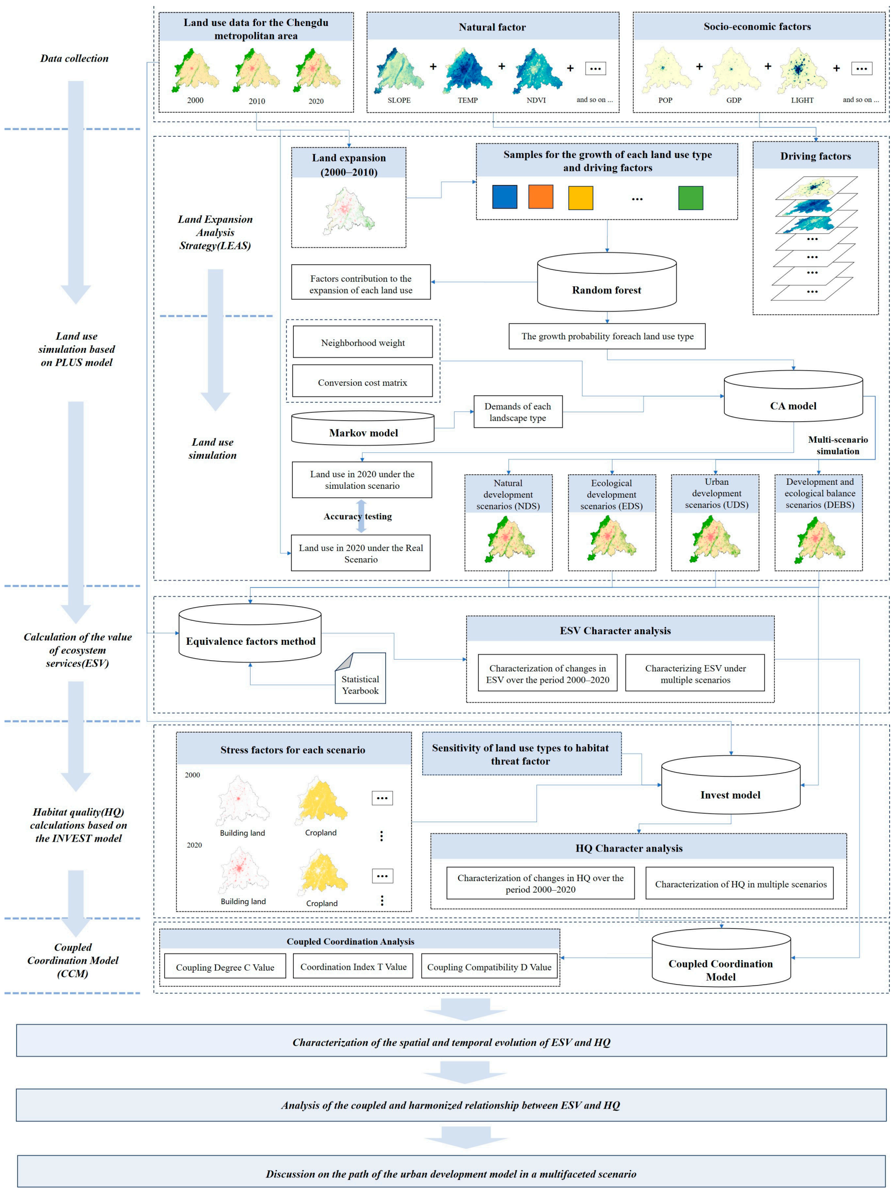

Figure 2. Research frame diagram.

2.3. Data Source

This research utilizes various datasets, including land use data, elevation data, slope data, population density data, nighttime light data, normalized difference vegetation index (NDVI) data, gross domestic product (GDP) data, road distance data, and railway distance data, as shown in Table 1. These datasets are crucial for the analysis and modeling conducted in the research.

Table 1. Data sources for the study.

Data Types	Data Name	Abbreviations	Data Description	Data Origins	Reference
Land use data	Land use	LU	Land use data for 2000, 2010, and 2020 within the study area, reflecting the type of land use within the unit space.	The GlobeLand30 data (www.globallandcover.com, accessed 24 June 2023)	[26,51,52]
Physical geography data	Elevation	DEM	Distribution of surface heights within the study area, reflecting the elevation of the surface per unit of space.	The geospatial data cloud platform (https://www.gscloud.cn/#page1/1, accessed 25 June 2023)	[26,51,52]
	Slope	SLOPE	Calculated from elevation data with the help of Arcgis 10.8, responding to the value of the slope per unit of space.	Using DEM elevation data and the slope analysis tool in ArcGIS 10.8, the slope information was obtained.	[26,51,52]
	Mean annual temperature	TEMP	Annual average surface temperature within the study area, reflecting the value of surface temperature per unit of space.	Earth data open access for open science (https://ladsweb.modaps.eosdis.nasa.gov/, accessed 26 June 2023)	[26,52]
	Normalized Difference Vegetation Index	NDVI	Vegetation cover on the ground surface within the study area, reflecting the amount of vegetation cover per unit of space.	The national ecological data center resource sharing service platform (http://www.nesdc.org.cn/, accessed 26 June 2023)	[26,51,52]
	Distance from water	WATER	Calculated from the watershed data in OpenStreetMap with the help of Acrgis 10.8, responding to the spatial distance of the unit from watersheds.	OpenStreetMap (https://www.openstreetmap.org/, accessed 26 June 2023)	[26,51,52]
Socio-economic data	Population	POP	Number of people within the study area, responding to the number of people per unit of space.	Worldpop (https://www.worldpop.org/, accessed 27 June 2023)	[26,51,52]
	Night light	LIGHT	Night-time light magnitude within the study area, responding to night-time light values per unit of space.	The Resource and Environmental Science and Data Center of the Institute of Geographical Sciences and Resources, Chinese Academy of Sciences (https://www.resdc.cn/, accessed 25 June 2023)	[26,51,52]

Table 1. *Cont.*

Data Types	Data Name	Abbreviations	Data Description	Data Origins	Reference
Socio-economic data	Gross domestic product	GDP	GDP values within the study area, responding to GDP values per unit of space.	The Resource and Environmental Science and Data Center of the Institute of Geographical Sciences and Resources, Chinese Academy of Sciences (https://www.resdc.cn/, accessed 25 June 2023)	[26,51,52]
	Distance to road	ROAD	Calculated from the road data in OpenStreetMap with the help of Arcgis 10.8, responding to the distance from the road per unit of space.	OpenStreetMap (https://www.openstreetmap.org/, accessed 26 June 2023)	[26,51,52]
	Distance to railroad	RAIL	Calculated from the railroad data in OpenStreetMap with the help of Arcgis 10.8, responding to the distance from the railroad per unit of space.	OpenStreetMap (https://www.openstreetmap.org/, accessed 26 June 2023)	[26,51,52]

2.4. Research Method

2.4.1. PLUS Mode

The Plus model builds upon the Flus model, integrating Land Expansion Strategy Analysis (LES) and Cell-based Auto-Regressive Spatial (CARS) modeling for land use prediction. While similar to other land use models, Plus, based on Cellular Automata (CA), overcomes the limitations of CA models in terms of strategic analysis.

In the workflow, the Plus model first identifies regions with changes in land use data over two periods. Then, using the Random Forest algorithm, it calculates the probabilities of various land uses and the driving factors contributing to land expansion based on land expansion analysis strategies.

Ultimately, employing the CA model with a foundation in multi-class random patch seeds, it replicates the process of land use generation to ascertain land use alterations.

LUC results from various factors. In this study, factors influencing LUC were selected from both natural and socioeconomic aspects. A total of 10 factors, including elevation, slope, NDVI, night-time light index, population density, road distance, and others, were comprehensively chosen as the driving factors for LUC, as listed in Table 1. These factors play a vital role in modeling and predicting LUC within the research area.

The domain weight represents the expansion capability of different land types and reflects the influence of different land types on each other.

$$\Omega_{i,k}^{t} = \frac{con\left(c_i^{t-1} = k\right)}{n \times n - 1} \times w_k \tag{1}$$

Within the equation, $\Omega_{i,k}^{t}$ stands for the land use type k's coverage ratio within its specific domain, signifying the neighborhood impact on the grid cell.

The expression $con\left(c_i^{t-1} = k\right)$ represents the total count of grid cells that were occupied by land use type k within the $n \times n$ window during the previous iteration; w_k is the variable weight attributed to various land use categories.

In this study, domain weight coefficients were determined by reviewing relevant research and considering the real circumstances within the study region (Table 2) [52].

Table 2. Table of domain weighting parameters.

Land Type	Cropland	Forest Land	Grassland	Waters	Unused Land	Building Land
Weights	0.129	0.113	0.097	0.111	0.048	0.072

To assess the model's precision, this research employed the Kappa coefficient for testing. The Kappa coefficient is a continuous value between 0 and 1, where a higher value indicates greater consistency. A Kappa value greater than 0.6 suggests good agreement [29]. The calculation equation is as presented below:

$$Kappa = \frac{P_o - P_c}{P_p - P_c} \tag{2}$$

In the equation, P_o represents the number of correctly simulated grids, P_c denotes the proportion accurately simulated under random circumstances, and P_p signifies the proportion accurately simulated in an ideal situation, typically taking a value of 1.

Based on land use data from 2000 and 2010, this study predicts the LUC for 2020. Comparing the predicted 2020 LUC with the actual data, the Figure of Merit (FOM) is 0.178, and the Kappa coefficient is 0.877, indicating high simulation accuracy.

2.4.2. Multi-Scenario Construction

This study aims to explore the various possibilities of land use change in future development. Four different development scenarios were set: Natural Development Scenario (NDS), Ecological Dominant Scenario (EDS), Urban development Scenario (UDS), and Development–Ecological Balance Scenario (DEBS). Based on previous research on multi-scenario simulations, this study adjusted the land use transition matrix obtained from Markov chains for the years 2010–2020. The adjustment was made according to the development characteristics of different scenarios. The following are detailed descriptions of the four scenarios:

(1) Natural Development Scenario (NDS):

The NDS maintains the original pattern of land changes without any intervention from influencing factors. The land use transition probability matrix is calculated based on the Markov chain, and the probabilities are the same as those in the 2010–2020 land use transition probability matrix [51,53]. This scenario is commonly used as a control experiment in previous studies on land use simulation to differentiate it from other scenario models.

(2) Ecological Dominant Scenario (EDS):

With the gradual deterioration of the global ecological environment, governments worldwide are increasingly focusing on environmental protection. Therefore, the ecological dominant scenario is considered a future development model. In this scenario, emphasis is placed on protecting ecological spaces and reducing human-induced damage and impact. Specifically, it involves the expansion of forest land, grassland, and water areas. The ecological dominant scenario has been identified as an important scenario model in many studies on ecological protection [54]. Additionally, the Chengdu metropolitan area has prominent natural features, and governments at all levels are actively promoting ecological protection and development, enacting corresponding protection and development policies. Based on previous research on the ecological dominant scenario [55,56], this study adjusted the original land use transition matrix. Specifically, the probability of conversion from building land to forest land, grassland, and water areas was increased by 30%, while the probabilities of conversion from forest land, grassland, and water areas to building land were decreased by 40%. The probability of conversion from cropland to building land was reduced by 10%, simulating land use changes under the dominance of ecological protection.

(3) Urban Development Scenario (UDS):

China's cities are still in a stage of outward expansion, and many studies have discussed development dominance as a future urban development scenario [57]. In the UDS, emphasis is placed on urban construction and development, specifically the expansion of urban building land. Based on previous research on the development dominance scenario [58], this study adjusted the original land use transition matrix. The probability of conversion from cropland, forest land, and grassland to building land was increased by 30%, while the probability of conversion from water areas to building land was increased by 10%. The probability of conversion from building land to cropland, forest land, grassland, and unused land was reduced by 30%, simulating land use changes under the dominance of development.

(4) Development–Ecological Balance Scenario (DEBS):

Balancing protection and development for sustainable development has always been emphasized by the Chinese government. In the DEBS, urban development and ecological protection are required to be coordinated. Therefore, attention should be given to both protection and development [59,60]. Many studies have used land use simulation software to simulate and evaluate sustainable urban development. Based on previous research on the development dominance scenario, this study adjusted the original land use transition matrix [61]. In terms of urban development, the probability of conversion from building land to cropland, forest land, grassland, and water areas was reduced by 10%. In terms of ecological protection, the probability of conversion from cropland to building land was reduced by 15%, while the probabilities of conversion from forest land, water areas, and grassland to building land were reduced by 10% [53].

2.4.3. Measurement of Habitat Quality

Within this study, the HQ module of the Invest model was employed to evaluate and compute the HQ for different counties within the Chengdu metropolitan area. The model's underlying principle integrates external threat factors, their respective intensities, and the sensitivity of various land use types to these threat factors in order to compute HQ values. The calculation equation is as presented below:

$$Q_{ik} = H_k\left(1 - \frac{M_{ik}^z}{M_{ik}^z + K^z}\right) \tag{3}$$

$$M_{ik} = \sum_{r=1}^{R}\sum_{y=1}^{Y_r}\left(\frac{W_r}{\sum_{r=1}^{R} W_r}\right) r_y i_{rxy} \beta_x S_{kr} \tag{4}$$

In this equation, Q_{ik} represents the HQ for land type k at spatial unit i, ranging from 0 to 1, where higher values indicate better HQ.

H_k represents the habitat suitability for land type k. M_{ik}^z signifies habitat degradation at spatial unit i, with z as a model default parameter set to 2.5. K is the half-saturation coefficient, usually configured at half of the maximum habitat degradation. R stands for the count of threat factors. Y_r denotes the number of spatial units in the threat layer within the land-type layer. W_r represents the weight assigned to the threat factor. r_y signifies the intensity of the threat factor's impact on habitats. i_{rxy} represents the threat level of the threat factor on habitats. β_x is indicative of the legal protection level. S_{kr} stands for the sensitivity of land type k to the threat factor.

This research, based on land use data for the Chengdu metropolitan area and a review of existing research, selected cropland, developed land, and unused land as the threat factors. Weightings were assigned and degradation types and their maximum impact distances were determined, as shown in Table 3. Sensitivity values for each land use type to the habitat threat factors were also established, as presented in Table 4 [26,62,63].

Table 3. Maximum impact radius and stress factor weight.

Threat Factor	Maximum Impact Distance/km	Weighting	Distance Decay Function
Cropland	1	0.2	Linear
Building land	8	0.6	Exponential
Unused land	3	0.5	Exponential

Table 4. Land use type sensitivity to habitat threat factors.

Land Type	Habitat Suitability	Building Land	Cropland	Unused Land
Cropland	0.3	0.6	0	0.5
Forest land	1	0.5	0.6	0
Grassland	0.7	0.6	0.8	0.4
Waters	0.7	0.8	0.7	0.4
Unused land	0.2	0.7	0.1	0
Building land	0	0	0	0

2.4.4. Ecosystem Service Value

Drawing from research by Costanza and others on ecosystem services, it is clear that ESV is a crucial metric for quantifying the benefits provided by ecosystems. Building upon the methodology of Xie Gaodi and his team for assessing ESV in China, a per unit area ESV table for the Chengdu metropolitan area was established, as presented in Table 5 [10,11,31,64].

$$E_a = \frac{1}{7} \times \sum_{i=1}^{3} \frac{P_i \times Q_i}{M_g} \tag{5}$$

Table 5. ESV per unit area in Chengdu metropolitan area (Unit: CNY/(hm^2·year·)).

Value of Ecosystem Services		Cropland	Forest Land	Grassland	Waters	Unused Land	Building Land
Supply Services	Food production	2160.55	737.13	965.89	2033.46	0.00	0.00
	Raw material production	1016.73	1677.61	1423.42	584.62	0.00	0.00
	Water supply	50.84	864.22	787.97	21,071.74	0.00	0.00
Regulating services	Gas regulation	1703.02	5515.76	5007.40	1957.21	50.84	0.00
	Climate regulation	915.06	16,521.87	13,242.91	5820.78	0.00	0.00
	Purification of the environment	254.18	4905.72	4371.94	14,107.14	25.42	0.00
	Hydrological regulation	686.29	12,048.26	9709.78	259,876.31	76.25	0.00
Support services	Soil conservation	2618.08	6735.84	6100.38	2363.90	50.84	0.00
	Nutrient maintenance	305.02	508.37	457.53	177.93	0.00	0.00
	Biodiversity	330.44	6125.80	5541.18	6481.66	50.84	0.00
Cultural services	Aesthetic landscapes	152.51	2694.34	2440.15	4804.05	25.42	0.00

In the equation, E_a represents the per unit area ESV provided by cropland (in CNY per hectare), where i signifies the chosen crop type, with a total of three categories. P_i denotes the average price (in CNY per kilogram) of the i-th crop in the study area, while Q_i represents the total yield (in kilograms) of the type i crop in the study area. M_g signifies the total cropland area for cultivation in the study area.

$$V_{jk} = e_{jk} \times E_a \tag{6}$$

In the equation, V_{jk} represents the ESV coefficient (in CNY per hectare) of the j-th land type in the study area for the k-th ecosystem service function, while e_{jk} represents the equivalence factor of the j-th land type in the study area for the k-th ecosystem service function.

$$E = \sum_{i=1}^{m} A_j \times V_{jk} \tag{7}$$

In the equation, E represents the total ESV in the study area (in CNY), and A_j represents the area (in hectares) of the j-th land type.

2.4.5. Coupling Coordination Model

The CCM is frequently employed to examine the extent of interactions and the level of harmonious development between two or more systems. It measures the coupling relationship between HQ and ESV, assessing the extent to which these two systems mutually influence each other. The equation is as follows:

$$T = aU_1 + bU_2 \tag{8}$$

T represents the comprehensive evaluation index. U_1 represents the values of HQ in various counties. U_2 represents the ESV in various counties. a and b are coefficients. In this case, both a and b are set to 0.5. A higher value of T indicates a higher overall ecological level.

$$C = \frac{\sqrt[2]{U_1 \times U_2}}{U_1 + U_2} \tag{9}$$

The equation is as follows: C represents the degree of coupling. A higher value of C signifies a more robust correlation between HQ and ESV, whereas a lower value of C indicates a weaker relationship between HQ and ESV.

$$D = \sqrt{C \times T} \tag{10}$$

The equation is as follows: D represents the degree of coordination. A greater D value indicates a heightened level of coordination between HQ and ESV, whereas a lower D value implies a diminished level of coordination between HQ and ESV.

Based on related research [65,66], the determination of coupling and coordination stages and types between ESV and HQ in the Chengdu metropolitan area is presented in the following table (Table 6).

Table 6. Coupling degree and coupling level.

Value of CC	Level of CC
$0 < D \leq 0.1$	Extreme dissonance
$0.1 < D \leq 0.2$	Severe dissonance
$0.2 < D \leq 0.3$	Moderate dissonance
$0.3 < D \leq 0.4$	Mild dissonance
$0.4 < D \leq 0.5$	On the verge of dissonance
$0.5 < D \leq 0.6$	Grudging coordination
$0.6 < D \leq 0.7$	Primary coordination
$0.7 < D \leq 0.8$	Intermediate coordination
$0.8 < D \leq 0.9$	Good coordination
$0.9 < D \leq 1$	Quality coordination

3. Results

3.1. Spatiotemporal Evolution Characteristics of Land Use in Chengdu Metropolitan Area

From the trends in land area changes, between 2000 and 2020, the building land of the Chengdu metropolitan area increased by 4.19%, while the unused land increased by 0.01%. However, the cropland area experienced a temporary increase from 2000 to 2010, but in the period from 2010 to 2020, it saw a decline. Specifically, from 2000 to 2010, the cropland area grew by 127.13 km^2, while from 2010 to 2020, it decreased by 2083.17 km^2. The forest land showed a pattern of decreasing from 2000 to 2010 by 872.6 km^2 but increased by 1357.17 km^2 from 2010 to 2020, resulting in a net expansion of 484.56 km^2 over the two decades. The grassland area has continued to increase slightly, expanding by a total of 24.51 km^2 over the 20-year period. The water area exhibited a trend of increasing until 2010 with a growth of 89.03 km^2, but it decreased by 33.19 km^2 from 2010 to 2020. In total, the water area expanded by 55.85 km^2 over the two decades.

In terms of spatial distribution (refer to Figure 3), during the period from 2000 to 2020, urban building land in the Chengdu metropolitan area expanded from the central area around Chengdu City outward to the periphery. Other counties and cities within the Chengdu metropolitan area also exhibited a similar pattern of expansion from the center towards the periphery. Cropland showed an initial trend of spreading into the mountainous areas in the northwest from 2000 to 2010. However, by 2020, this expansion trend had disappeared, and cropland, on the whole, demonstrated a shrinking pattern. Forest land showed a contraction trend from 2000 to 2010, with the main changes occurring in the mountainous regions in the northwest, where forest land was converted to cropland. In 2020, the forest land started to grow again, with significant expansion in the mountainous regions of both the northwest and southwest. There were also minor expansions in the central mountainous areas and the plain areas in the southeast. The water area experienced minimal changes from 2000 to 2020, mainly involving slight expansions in the northern mountainous regions. Grassland and unused land showed no significant changes over the two-decade period.

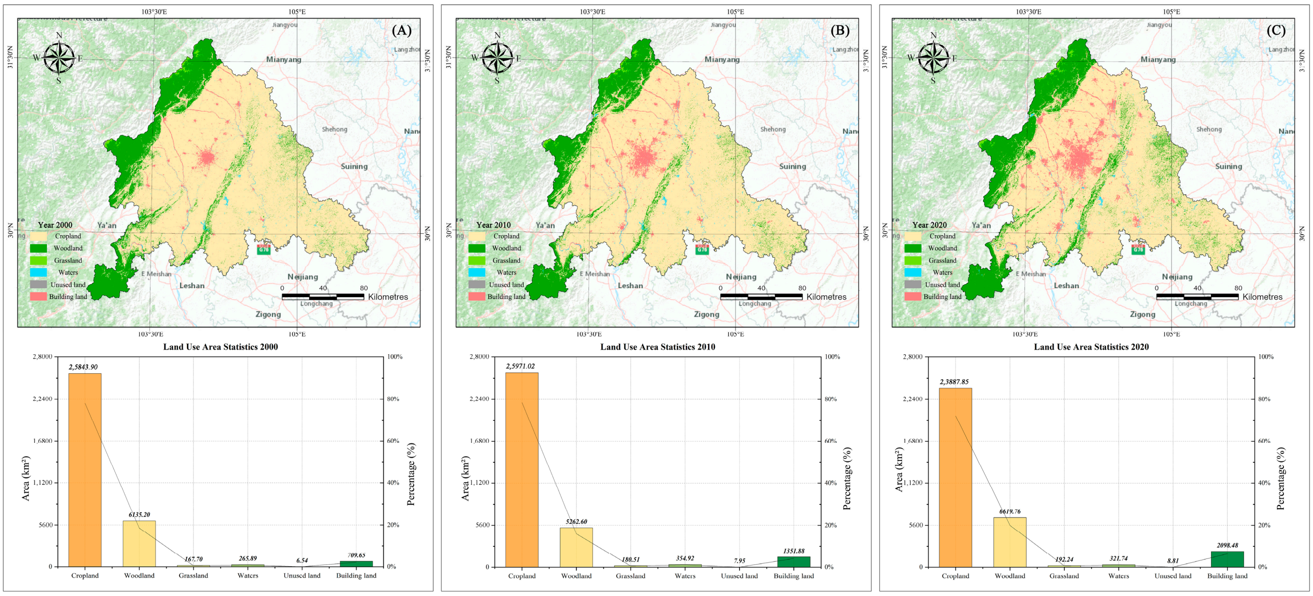

Figure 3. LUC map and area statistics of Chengdu metropolitan area from 2000 to 2020: (**A**) 2000, (**B**) 2010, and (**C**) 2020.

Based on the simulation results for the four scenarios in 2030 (Figure 4), under the NDS, cropland decreased to 22,084.42 km^2, forest land expanded to 7752.49 km^2, grassland decreased to 106.45 km^2, water area expanded to 400.51 km^2, and building land expanded to 2775.66 km^2. Compared to the NDS, in the EDS, there was some growth in ecologically related land uses, with cropland, forest land, and grassland all experiencing growth, while the area of building land decreased. Similarly, compared to the NDS, under the UDS, cropland, forest land, and waters experienced reductions, while building land showed a significant increase, adding 209 km^2. In the DEBS, compared to the NDS, cropland, forest land, and waters, experienced slight increases, while grassland and building land experienced slight decreases.

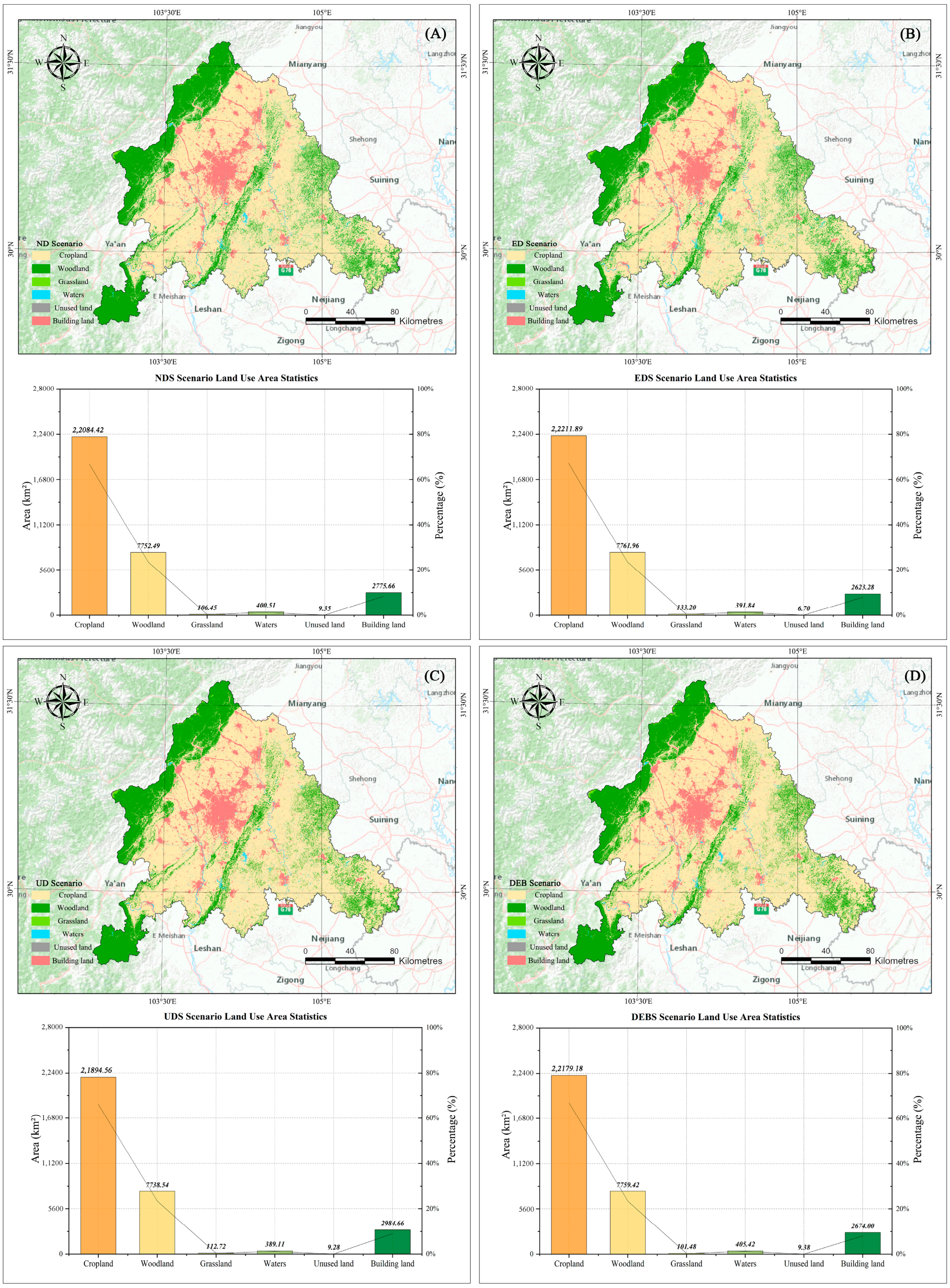

Figure 4. LUC map and area statistics of Chengdu metropolitan area under four scenarios: (**A**) NDS, (**B**) EDS, (**C**) UDS, and (**D**) DEBS.

3.2. Characteristics of Spatial and Temporal Evolution of ESV in Chengdu Metropolitan Area

Using the adjusted unit area ESV coefficient table and land use data for various cities within the Chengdu metropolitan area, the ESVs for each city within the Chengdu metropolitan area from 2000 to 2020 were calculated, as well as the ESVs under four different scenario simulations.

In terms of trend changes (Figure 5), from 2000 to 2020, the ESVs of Chengdu and Deyang cities decreased around 2010, but gradually began to rise again. Meanwhile, Meishan and Ziyang cities showed a consistent upward trend in ESV. Considering the simulation results of the four different scenarios, Chengdu, Deyang, and Ziyang cities exhibited similar patterns across all scenarios. Specifically, the ESV peaked under the DEBS and reached its lowest under the UDS. However, Meishan city differed from the others, with relatively lower ESVs under the EDS and UDS but relatively higher ESVs under the DEBS. Overall, except for Meishan city, the ESV reached its maximum value under the DEBS in the Chengdu metropolitan area, followed by the EDS and NDS, while the ESV was lowest under the UDS.

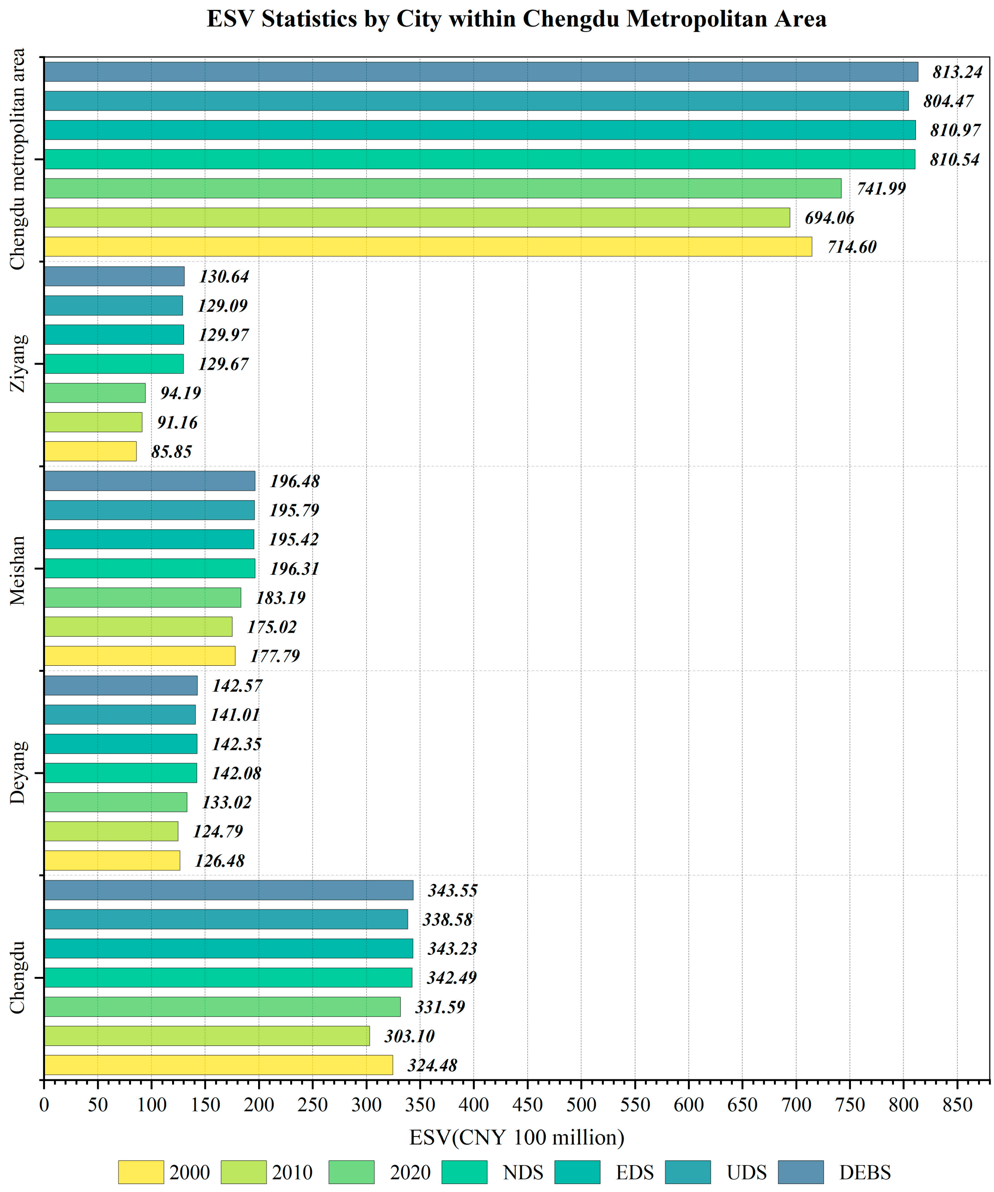

Figure 5. ESV statistics by city within Chengdu metropolitan area.

From different city perspectives, Chengdu has a significantly higher ESV compared to the other three cities. Meishan's ESVs are higher than those of Deyang and Ziyang. Deyang and Ziyang have relatively lower ESVs among the four cities in the study area, with Deyang's values slightly higher than Ziyang's. Ziyang has the lowest ESV among the four cities.

3.3. Characteristics of Spatial and Temporal Evolution of HQ in Chengdu Metropolitan Area

The study utilized the HQ module of the Invest model to generate HQ distribution maps for the Chengdu metropolitan area in the years 2000, 2010, and 2020, as well as under various scenario simulations. These HQ maps were further categorized into five quality levels using ArcGIS 10.8 software: Very low HQ (0–0.15), Low HQ (0.15–0.4), Medium HQ (0.4–0.7), High HQ (0.7–0.9), and Very high HQ (0.9–1).

In terms of spatial distribution (refer to Figure 6), within the Chengdu metropolitan area from 2000 to 2020, the very low HQ areas mainly expanded outward from the urban centers, while, correspondingly, the low HQ areas decreased in size. The medium HQ areas were predominantly located in the northwestern Longmen Mountains, the central Longquan Mountains, and the southeastern plains of the metropolitan area. During the period from 2000 to 2010, there was a declining pattern observed in the medium HQ area near the northwestern Longmen Mountains, while the southeastern plain areas experienced a rising trend. In the subsequent period from 2010 to 2020, the medium HQ areas showed a slight contraction. Areas with high and very high HQ were mainly distributed in the northwestern Longmen Mountains, southwestern Wawushan Mountains, the central Longquan Mountains, and the eastern plains. From 2000 to 2010, the areas with high and very high HQ near the northwestern Longmen Mountains and in the eastern plains showed a shrinking trend. However, in the period from 2010 to 2020, areas surrounding the northwestern Longmen Mountains, the central Longquan Mountains, and the eastern plains displayed noticeable expansion in high and very high HQ regions.

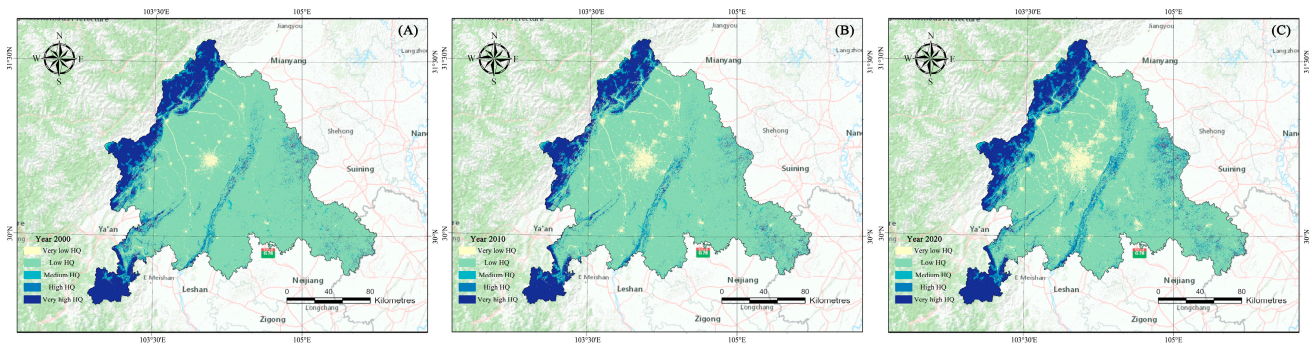

Figure 6. Changes in HQ in the Chengdu metropolitan area during the period 2000–2020: (**A**) 2000, (**B**) 2010, and (**C**) 2020.

Across the four distinct scenarios, it is evident that HQ within the study area will exhibit an ascending trend in 2030 (refer to Figure 7). Under the EDS, HQ is the best among the four scenarios. The areas with high and very high HQ cover 7761.96 km^2, accounting for 23.43% of the total study area. Conversely, under the UDS, HQ is the poorest among the four scenarios. Areas with low and very low HQ cover 25,046.83 km^2, representing 75.60% of the total study area. Under the DEBS scenario, areas with high and very high HQ cover 7759.42 km^2, making up 23.42% of the total study area, which is second only to the EDS scenario. Under the NDS scenario, areas with high and very high HQ cover 7752.49 km^2, representing 23.40% of the total study area, slightly higher than the UDS.

Combining the observations from the figure (Figure 8), it is evident that, during the period from 2000 to 2020, HQ within the study area exhibited an overall upward trend, with the exception of a decline in 2010. During the period, regions with relatively high and very high HQ increased by 1.46%, while areas with relatively very low and low HQ decreased by 1.61%. However, in 2010, there was a noticeable decrease in HQ across the study area. Compared to 2000, regions with relatively high and very high HQ decreased by 2.63% in 2010, while areas with relatively very low and low HQ increased by 2.43%.

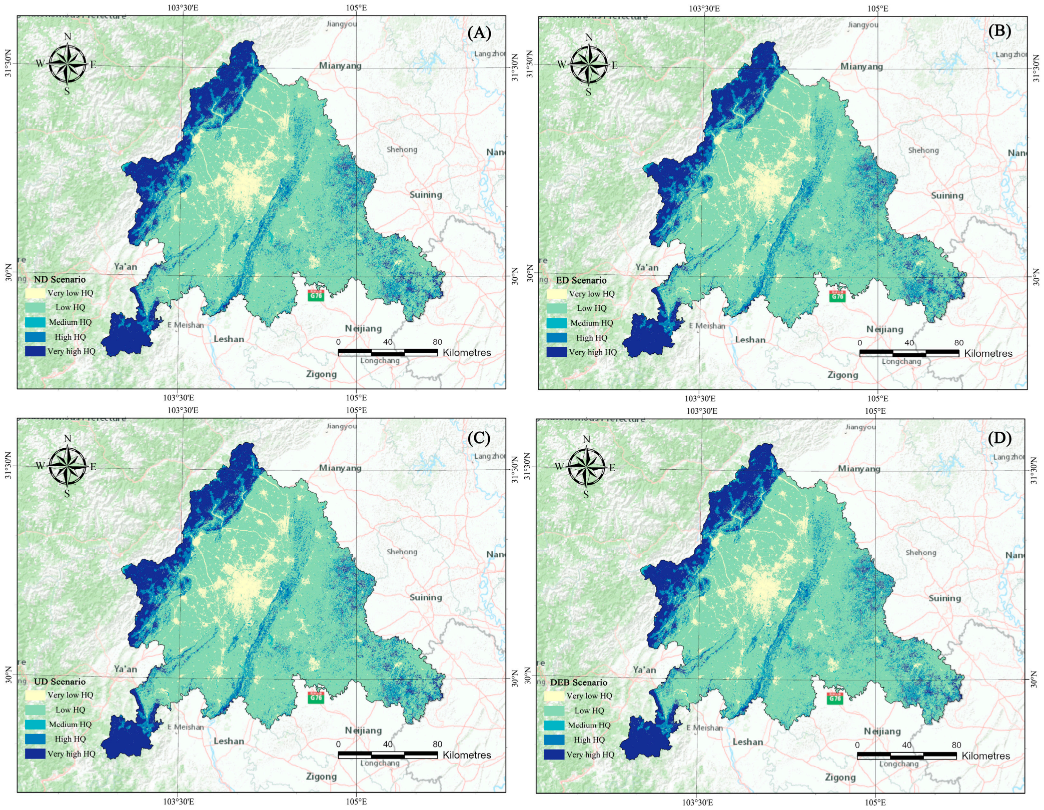

Figure 7. HQ changes in the Chengdu metropolitan area under four scenarios are as follows: (**A**) NDS, (**B**) EDS, (**C**) UDS, and (**D**) DEBS.

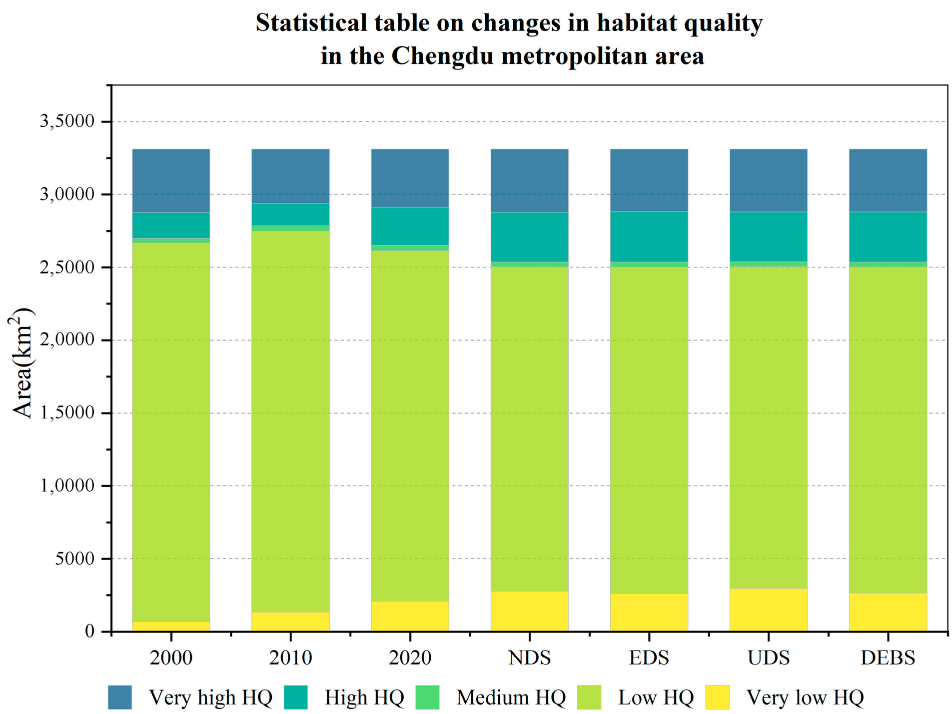

Figure 8. Statistical table on changes in HQ in the Chengdu metropolitan area.

From the perspective of various cities within the Chengdu metropolitan area (as shown in Figure 9), the average HQ also experiences changes. Chengdu, Meishan, and Deyang have slightly higher average HQ values than Ziyang. In terms of the trend, Chengdu and Meishan show similar patterns, with 2000 being the year of the highest average HQ. After a decrease in 2010, it started to rise again after 2020. Considering the four different scenario simulations, Chengdu has higher average HQ values in the EDS (0.38267) and DEBS (0.38273) scenarios compared to NDS (0.38064) and UDS (0.37876). Meishan's average HQ value is slightly higher under NDS (0.40702) compared to EDS (0.40683), DEBS (0.40685), and UDS (0.40566). In the case of Deyang city, the average HQ values exhibited a trend of initially decreasing and then increasing from 2000 to 2020, similar to Chengdu city. The maximum value was observed under the EDS scenario (0.39738), and the minimum value occurred under the UDS scenario (0.39501). However, Ziyang city showed a different pattern compared to the other three cities. Ziyang city demonstrated a continuous upward trend from 2000 to 2020. In scenario simulations, it reached its maximum value under DEBS (0.35479) and its minimum value under UDS (0.35244). Overall, in the Chengdu metropolitan area, the HQ exhibited a trend of initially decreasing and then increasing from 2000 to 2020. Across the four simulated scenarios, the average HQ values ranked from highest to lowest as follows: EDS (0.39794), NDS (0.39662), UDS (0.39469), and DEBS (0.37720).

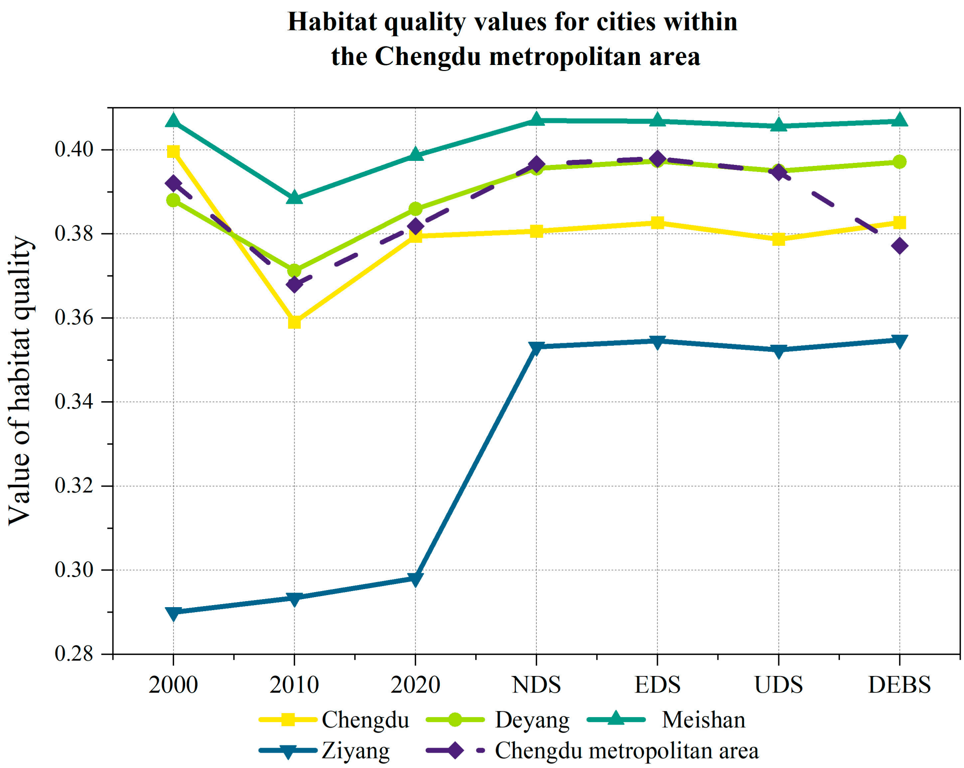

Figure 9. HQ values for cities within the Chengdu metropolitan area.

3.4. Coupling and Harmonization of ESV and HQ under Multi-Scenario Modeling

The study utilized CCM to calculate the CC values of ESV and HQ for each city within the Chengdu metropolitan area from 2000 to 2020 under four different scenario simulations (Table 7). Overall, the CC values between ESV and HQ fluctuated minimally, and each city within the metropolitan area exhibited a relatively stable state. Specifically, during the period from 2000 to 2020, Chengdu city showed grudging coordination, Deyang city was on the verge of dissonance, Meishan city exhibited grudging coordination, and Ziyang city showed mild dissonance and was on the verge of dissonance. Meanwhile, during the same period, Chengdu city had the highest average CC value (0.5841), followed by Meishan city (0.5112), Deyang city (0.4656), and Ziyang city (0.3998). Spatially, areas with higher CC values were located in the western part of the metropolitan area, primarily comprising Chengdu city, Meishan city, and Deyang city, while Ziyang city in the eastern region had relatively weaker CC values.

Table 7. Coupled harmonization of ESV and HQ in Chengdu metropolitan area.

Region	Year	2000	2010	2020	NDS	EDS	UDS	DEBS
Chengdu	Coordination Index T Value	0.3618	0.3456	0.3533	0.3352	0.3358	0.3342	0.3355
	Coupling Degree C Value	0.9668	0.9645	0.9642	0.9654	0.9655	0.9657	0.9657
	CC Value	0.5914	0.5773	0.5837	0.5689	0.5694	0.5681	0.5692
	CC Degree	Gc	Gc	Gc	Gc	Gc	Gc	Gc
Deyang	Coordination Index T Value	0.2193	0.2215	0.2217	0.2165	0.2168	0.2167	0.2166
	Coupling Degree C Value	0.9813	0.9822	0.9816	0.9818	0.9818	0.9817	0.9818
	CC Value	0.4639	0.4664	0.4665	0.461	0.4613	0.4612	0.4611
	CC Degree	Od	Od	Od	Od	Od	Od	Od
Meishan	Coordination Index T Value	0.2615	0.2637	0.2599	0.2537	0.2525	0.2542	0.2529
	Coupling Degree C Value	0.9988	0.9991	0.9988	0.999	0.999	0.9991	0.999
	CC Value	0.5111	0.5133	0.5095	0.5034	0.5023	0.504	0.5026
	CC Degree	Gc	Gc	Gc	Gc	Gc	Gc	Gc
Ziyang	Coordination Index T Value	0.1579	0.1697	0.1655	0.195	0.1952	0.1954	0.1955
	Coupling Degree C Value	0.9712	0.9743	0.9726	0.9838	0.9839	0.984	0.9841
	CC Value	0.3915	0.4066	0.4012	0.438	0.4383	0.4385	0.4386
	CC Degree	Md	Od	Od	Od	Od	Od	Od

Note: Gc: Grudging coordination; Od: On the verge of dissonance; Md: Mild dissonance.

Considering the four scenario simulations, each city within the Chengdu metropolitan area exhibited different characteristics in CC values under different scenarios. Chengdu city and Deyang city reached their maximum under EDS, while Meishan city peaked under UDS, and Ziyang city reached its maximum under DEBS. Moreover, the CC values under DEBS were relatively high, with all cities except Meishan city ranking within the top two among the four scenarios. Additionally, the CC values under UDS and NDS were slightly lower overall compared to EDS and DEBS. In conclusion, overall, the CC values of each city within the Chengdu metropolitan area were slightly higher under EDS and DEBS compared to other scenarios, with some variations among cities.

4. Discussion

4.1. Characterization of the Spatial and Temporal Evolution of ESV and HQ

In light of current research, it is evident that LUC has a significant impact on ESV and HQ [36]. An examination of land use changes in the Chengdu metropolitan area from 2000 to 2020 reveals a marked decline in the extent of forest land in 2010 compared to the figures from both 2000 and 2020. Conversely, the area of cropland in 2010 surpassed the figures recorded for 2000 and 2020. Furthermore, the urban building land area in the Chengdu metropolitan area experienced continuous expansion from 2000 to 2020. These characteristic changes can be attributed to the rapid pace of urbanization in China following the implementation of the reform and opening-up policy. The urbanization rate has increased significantly, leading to a continuous expansion of urban building land area, which, in turn, has resulted in a continual shrinking of cropland [47]. The 2008 Wenchuan earthquake had a significant impact on vegetation in the Chengdu region, resulting in a sharp decline in forest land. Nevertheless, the Chinese government gradually acknowledged the risks associated with the decline of cropland and forest land areas, leading to the introduction of protective policies starting in 2003. Consequently, the cropland area peaked in 2010. Nonetheless, as the Chengdu metropolitan area continued to grow, experiencing population influxes and government policy directives, urban expansion ensued, leading to the conversion of a substantial portion of cropland [67].

Concerning ESV, the Chengdu metropolitan area experienced an initial decline followed by an subsequent increase. The ESV in the Chengdu metropolitan area was lower in 2010 compared to both 2000 and 2020. The decrease in ESV in 2010 was linked to the substantial reduction in forest land area in the Chengdu metropolitan area, mainly attributable to the devastation caused by the Wenchuan earthquake. Previous studies have indicated that forest land and grassland make greater contributions to ESV compared to other land use categories [12,14]. In various scenario simulations, under the DEBS, all four cities within the Chengdu metropolitan area attained the maximum ESV. In the UDS, Chengdu, Deyang, and Ziyang had the lowest ESV, while in the EDS, Meishan had the lowest ESV. Prior research has demonstrated that natural elements such as cropland, forest land, and water bodies are the primary contributors to ESV. Cropland, forest land, and water areas can effectively enhance the ESV of a region [68]. Therefore, under the UDS, where building land area increases and natural elements decrease relatively, this leads to a decrease in ESV. When considering Meishan, in the UDS, urban expansion encroaches upon forest land, grassland, and waters, resulting in a reduction in ESV [69]. However, as the Chinese government strengthens the construction of ecological civilization, more waters and forest land areas are brought under protection. Urban expansion frequently comes at the cost of cropland [70]. This leads to a reduction in cropland area, an increase in waters and forest land area, and, as shown in Table 4, it is evident that the ESV per unit area for waters and forest land is much higher than for cropland. Thus, under the UDS, the ESV surpasses that of the other scenarios.

Regarding HQ, in 2010, fewer areas in the Chengdu metropolitan area exhibited high and very high HQ levels compared to those in 2000 and 2020. This decline in 2010 can also be attributed to the influence of the Wenchuan earthquake on the Chengdu metropolitan area, causing disruption to local ecosystems and thereby impacting HQ. There has been a sharp decrease in the number of forested areas. Meanwhile, China underwent rapid development from 2000 to 2010, characterized by the continuous outward expansion of cities. Previous studies have indicated that both forested areas and grasslands contribute to the enhancement of HQ, while urban development land affects HQ development [71]. Consequently, HQ in the Chengdu metropolitan area was lower in 2010 compared to that in 2000 and 2020. Despite relatively small fluctuations in HQ values across all four scenarios, distinctions are still discernible. Under the UDS, the HQ values for all four cities within the Chengdu metropolitan area are the lowest. This indicates that urban construction and development exert a notable influence on HQ, consistent with previous research findings [72]. Concerning maximum HQ values, cities in the EDS, NDS, and DEBS scenarios attain the highest HQ levels. This relationship may be attributed to local natural resource conditions [73]. Hence, further investigation into the relationship between ESV and HQ is necessary to ascertain the optimal development model.

4.2. Analysis of the Coupled and Harmonized Relationship between the ESV and HQ

Considering the findings from the CCM, Chengdu city demonstrates higher CC values between ESV and HQ compared to the other cities within the Chengdu metropolitan area. Chengdu and Meishan exhibit a begrudging coordination between ESV and HQ, as indicated by their CC values. Conversely, ESV and HQ in Deyang and Ziyang cities approach a state of discord. The Chengdu city government has prioritized the development of ecological civilization as a core component of urban development, particularly evident with the introduction of the “ecological civilization construction” policy. This focus has led to the protection of natural ecosystems. Meishan benefits from a favorable natural resource situation, resulting in relatively high ESV and HQ values. Consequently, Chengdu and Meishan demonstrate a state of begrudging coordination between ESV and HQ. While Deyang plays a vital role in food production for China, its HQ remains relatively poor. Consequently, the CC of ESV and HQ in Deyang City is on the verge of dissonance. Ziyang city is located in a plain area with relatively dispersed natural resources. Both HQ and ESV are at relatively low levels in Ziyang city, resulting in a state of "the verge of disorder" between ESV and HQ.

Analyzing the temporal changes specifically, the CC values between ESV and HQ in various cities exhibited a relatively stable trend from 2000 to 2020, albeit with some fluctuations. Since the beginning of the 21st century, the Chinese government has placed increasing emphasis on environmental protection and introduced the concept of ecological civilization in 2007. As a result, the overall quality of the ecological environment improved, leading to a gradual increase in the CC values between ESV and HQ during this period. Nonetheless, the significant decrease in the CC values between ESV and HQ resulted from the devastating impact of the 2008 Wenchuan earthquake on vegetation in the mountainous areas of the northwestern part of the Chengdu metropolitan area [74]. With ongoing urban development and outward expansion, slight declines were observed in the CC between ESV and HQ. For instance, Meishan and Ziyang, characterized by lower levels of urban development compared to Chengdu and Deyang [75], were still undergoing phases of urban expansion. This led to a certain degree of decline in the CC values between ESV and HQ in these cities. Meanwhile, Chengdu and Deyang had shifted their focus from urban expansion to prioritizing ecological security and protection [76], leading to an increase in the CC values between ESV and HQ during the same period.

Considering the findings from multiple scenario simulations, Chengdu and Deyang exhibited the highest CC values between ESV and HQ under the EDS. Meishan demonstrated the highest CC between ESV and HQ under the UDS. Ziyang showed the highest CC between ESV and HQ in the DEBS. Therefore, considering these experimental simulation results alongside the current state of urban development, it is evident that Chengdu and Deyang, characterized by relatively high levels of overall urban development, encounter challenges in harmonizing ecological protection with urban development under the NDS. The maximum CC between ESV and HQ can only be achieved under the EDS, which emphasizes stronger ecological protection. Thus, it is apparent that Chengdu and Deyang should adhere to policies and measures for ecological protection in their future development. The choice of this development model might be linked to the decline in HQ resulting from the rapid urban expansion in Chengdu and Deyang in the past. Rapid urban expansion has led to a decline in HQ [77], creating an imbalance between ESV and HQ. The results of this study are also consistent with the recent development policies of Chengdu [78].

Likewise, taking into account the prevailing patterns of urban development, Meishan is endowed with natural ecological features such as the Longquan Mountain and the Min River, contributing to its favorable ecological environment [76]. However, the city's development fails to align with its ecological advantages, resulting in a mismatch between HQ and ESV. Thus, under the UDS, optimizing the allocation of resources towards urban ecological environment protection in future development endeavors can maximize the CC between ESV and HQ. As for Ziyang, characterized by a relatively lower overall development level and a less favorable ecological environment [75,76], the DEBS, emphasizing both urban development and ecological environment protection, leads to the highest CC between urban ESV and HQ.

In conclusion, when comparing various cities within the Chengdu metropolitan area, it is evident that each city differs in terms of urban development level and natural environmental characteristics, leading to variations in the coupling and coordination levels of ESV and HQ. Therefore, it is necessary to analyze the characteristics of each city at different levels and formulate future development models accordingly.

4.3. Discussion on the Path of the Urban Development Model in the Multifaceted Scenario

This study found significant differences in the coupling and coordination relationship between ESV and HQ under different scenario simulations. Taking into account the coupling and coordination relationship between the value generated by the ecosystem in the Chengdu metropolitan area from 2000 to 2020 and its environmental quality, as well as the degree of coupling and coordination between the value generated by the ecosystem and its environmental quality under different development models, the following three choices for urban development paths were explored in depth (Figure 10):

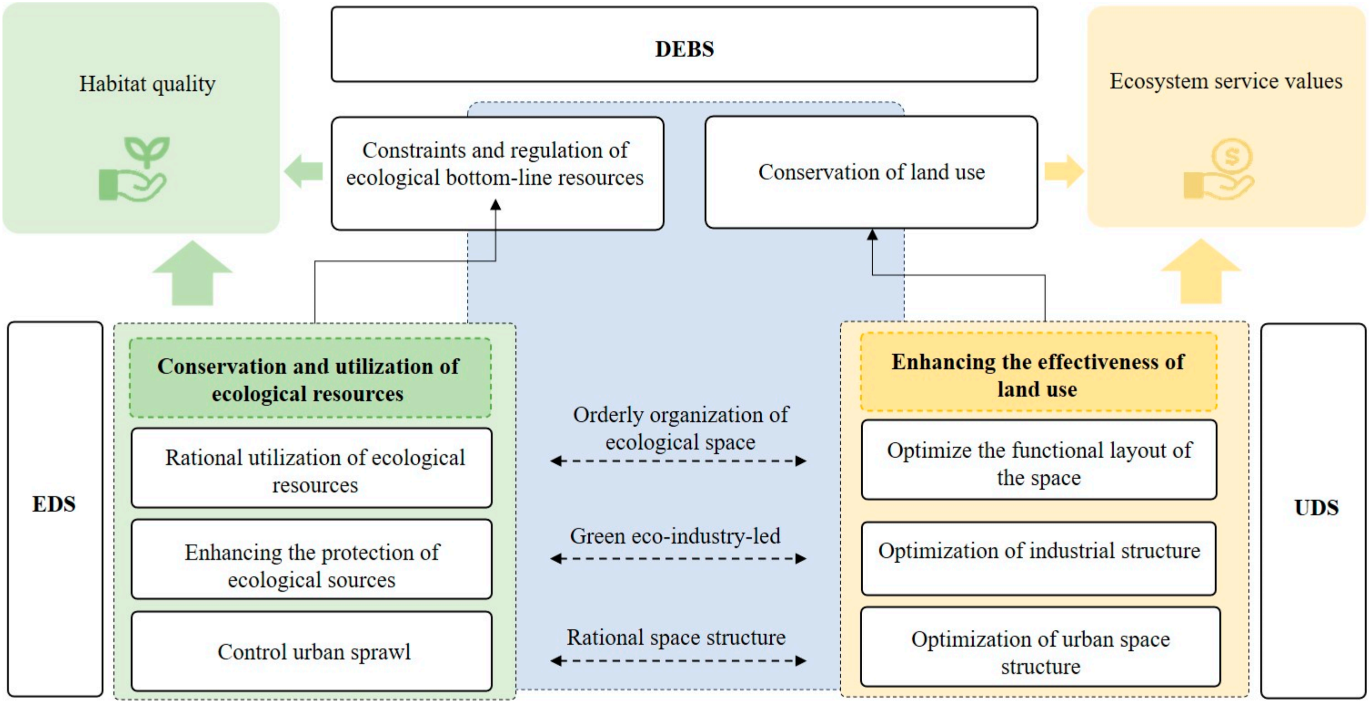

Figure 10. Path map of the urban development model.

(1) Ecological development scenario (EDS): Under the EDS, urban development focuses on ecological conservation, primarily aimed at the protection and sustainable utilization of ecological resources. This approach is not only for the preservation of ecological resources but also respects the spatial requirements and limitations of the city. For example, in cities like Chengdu and Deyang, rapid urban development and construction in the past have had a significant impact on the ecological environment. Cities that have experienced rapid development often suffer certain damages to their ecological environment [79]. Therefore, for such cities, emphasis should be placed on ecological protection. Specifically, they should strengthen the protection of ecological source areas such as the Long-quan Mountains and Longmen Mountains within the Chengdu metropolitan area, through measures such as enhancing ecological protection boundaries, implementing ecological compensation, and strengthening supervision of ecological source areas, to protect the diversity of ecological resources within the source areas, thereby enhancing HQ values. Additionally, within the bounds of not disrupting the ecological balance, it allows for the rational development and utilization of ecological resources, enhancing the efficiency of resource transformation, and consequently raising HQ. Simultaneously, it is important to control the uncontrolled sprawl of cities that causes damage to ecosystems, and plan urban and ecological spaces reasonably to establish a spatial layout where urban and ecological areas are mutually coordinated. In practical terms, many cities around the world have already adopted development models led by ecology, ensuring coordination between the ecological environment and economic development. Kitakyushu in Japan is one such example. Due to its previously unregulated urban development, Kitakyushu faced environmental degradation. However, under the establishment of an ecologically led development model, the government, businesses, and the public collaborated to protect environmental resources. Simultaneously, efforts were made to upgrade and transform traditional industries, as well as develop emerging environmental protection industries [80].

(2) Urban development scenarios (UDS): Under the UDS, urban development predominantly leans towards construction and development. However, this is not a form of chaotic urban sprawl. Unplanned urban sprawl can be detrimental to increasing both ESV and HQ [69,81]. For example, Meishan City has a relatively good ecological environment, but its level of urban development is relatively low, with low land-use efficiency. There are still many cities in China with similar low land-use efficiency [82,83]. In the urban development model, such cities should focus on improving urban land-use efficiency. Specifically, Meishan City should optimize the functional layout of urban spaces. This involves planning the layout of various functional spaces within the city in a rational manner, coordinating blocks with similar or related functions, thereby enhancing the efficiency of various production and living activities within the city and improving its operational efficiency [84]. Secondly, optimizing the spatial structure of the city involves appropriately adopting a multi-center structure, dispersing and reorganizing various functions within the city, thereby improving land utilization efficiency and providing the necessary space for the development of ecosystems, thereby enhancing the levels of ESV and HQ [85]. Furthermore, advancing industrial upgrading and transformation, optimizing the efficiency of the industrial structure, increases land-use efficiency and avoids the wastage of land resources that could result in declining HQ and ESV [86,87]. Currently, many countries and regions around the world are also exploring intensive urban development models. For example, Singapore adopts the Transit-Oriented Development (TOD) model, which involves the rational planning of various functional land uses and transportation hubs, achieving intensive and mixed land use [88]. Similarly, Sydney adopts a polycentric urban spatial structure, which has alleviated urban pressures to some extent and improved land use efficiency [89].

(3) Development–Ecological Balance Scenario (DEBS): Under the DEBS, urban development stresses a balance between development and conservation. This balanced approach falls between the extremes of EDS and UDS. In this scenario, the focus is on regulating ecological baseline resources while also emphasizing the efficient use of land. For example, in Ziyang City, there are certain issues with both the level of economic development and the quality of the ecological environment. In the process of construction and development, cities like this may encounter obstacles due to deviations in their choice of development path and direction, resulting in relatively poor ecological environment quality [90]. In the development process, these cities should focus on the coordinated protection and development of both aspects. This is achieved through the organized distribution of ecological spaces alongside other spaces. It calls for the rational utilization of ecological space, the increased protection of ecological resources, and the enhancement of both ESV and HQ [91]. It also encourages the efficient use of green resources, the development of green and ecological industries, and the optimization of land-use efficiency, thereby increasing ESV [87]. Moreover, it is imperative to organize urban spatial structures rationally and enforce strict control over urban development boundaries to mitigate declines in ESV and HQ caused by uncontrolled urban sprawl during the development process.

In summary, due to the complex and contradictory relationship between urban development and ecological conservation, many cities struggle to reconcile the two, leading to a situation of imbalance between development and protection. In response to the problems identified in urban development, this study proposes three different models to address this imbalance. EDS and UDS represent two distinct development paths, suitable for cities where there is a unilateral imbalance between urban development and ecological conservation, while DEBS focuses on cities where both protection and development are lacking to some extent. The application of these three models needs to be tailored to the specific developmental stage of each city. After assessing the development issues faced by each city, targeted plans for future urban development can be formulated, thereby achieving a sustainable development path that harmonizes urban development with ecological conservation.

4.4. The Limiting Factors of This Study

This study adopts a macro perspective, focusing on land use types, utilizing the Plus model to simulate urban land use change (LUC) across various scenarios, and employing the Invest model and equivalent factor method to examine the correlation between ESV and HQ in different development scenarios. However, this study faces the following constraints:

Firstly, this study utilized the PLUS model to simulate LUCs across four distinct scenarios. However, it would be more comprehensive to incorporate additional constraint factors, such as ecological protection redlines and cropland protection redlines, during the simulation process.

Secondly, for measuring HQ, this study utilized the Invest model and integrated various stress factors and their impact levels on different land types. However, it would be more precise to incorporate additional stress factors, such as plot ratio, building density, air quality, and other relevant factors, when assessing HQ.

Finally, this study addressed the relationship between ESV and HQ from a relatively macro-level research perspective, with limited discussion of the impact of various land types on ESV and HQ at the micro-level. Collecting more precise land use data would enable a detailed exploration of the relationships between different land types and their impact on ESV and HQ, thus fostering a more comprehensive understanding of the operational mechanisms governing ESV and HQ.

5. Conclusions

Since the industrial revolution, cities have undergone rapid development, accompanied by environmental pollution. In response to the ongoing degradation of the ecological environment, various disciplines are actively exploring models and pathways for sustainable urban development. This study, through simulations of future urban development and the measurement of ESV and HQ values, utilized CCM to investigate the CC relationship between ESV and HQ in various cities within the Chengdu metropolitan area. The results are utilized to discuss the developmental trajectories of cities under diverse scenarios. This study unveils the following insights:

(1) Between 2000 and 2020, the land use pattern in the Chengdu metropolitan area underwent significant changes, mirroring the trends in other rapidly developing Chinese cities. Initially, there was a decade of rapid urban expansion, marked by the outward expansion of built-up areas, leading to environmental degradation. However, with the implementation of ecological conservation policies, this expansion gradually decelerated. Consequently, there were fluctuations in cropland and forest land areas during this twenty-year period.

(2) From 2000 to 2020, the ESV in the Chengdu metropolitan area exhibited an initial decrease followed by an increase. Under different scenarios, the ESV values ranked from highest to lowest were DEBS, NDS, EDS, and UDS. Chengdu City and Deyang City witnessed an initial decrease followed by an increase, while Deyang City and Ziyang City experienced continuous growth. The ranking of ESV values among cities was Chengdu City, Meishan City, Deyang City, and Ziyang City.

(3) Over the same period, HQ in the Chengdu metropolitan area showed an initial decrease followed by growth. Regions with poor HQ expanded outward with urban expansion, while those with moderate HQ remained relatively stable. Areas with good and relatively good HQ were clustered around mountainous water systems, displaying a trend of initial contraction followed by expansion. Under different scenarios, HQ values ranked from highest to lowest were EDS, NDS, UDS, and DEBS. Meishan City exhibited the highest HQ, whereas Ziyang City had the lowest. The HQ values of Deyang City and Chengdu City were relatively similar.

(4) ESV and HQ demonstrate variations across cities and planning scenarios, highlighting the regulatory role of urban planning in ecological conservation. The CC of ESV and HQ in the four cities within the Chengdu metropolitan area exhibits diverse trends: Chengdu City and Meishan City are marginally coordinated, Deyang City is approaching

imbalance, and Ziyang City is on the brink of imbalance. Regarding scenario simulations, Chengdu City and Deyang City achieve their maximum CC value under the EDS scenario, Meishan City under the UDS scenario, and Ziyang City under the DEBS scenario.

The findings of this study reveal a complex dynamic relationship between urban development and ecological conservation, emphasizing the need for comprehensive consideration of factors such as land use, natural environmental adjustments, and policies to achieve a balance between the two. Additionally, variations in ESV and HQ performance among different cities underscore the importance of accounting for specific local conditions and demands in urban planning and environmental protection policies. Future research should concentrate on optimizing the balance between urban development and environmental protection under various geographical, natural, and social conditions, as well as enhancing the efficiency and effectiveness of urban planning through technological innovation and management improvements. This study offers a robust evaluation framework and technical pathways, constructing four different development scenarios and corresponding strategies, aiming to guide urban planning and development in similar regions.

Author Contributions: G.H.: writing—original draft, software, data curation. C.H.: writing—article revision, supervision. S.F.: writing—article revision, software, supervision. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Social Science Foundation of China (No. 22BMZ048).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

References

1. Allen, C.; Malekpour, S. Unlocking and Accelerating Transformations to the SDGs: A Review of Existing Knowledge. *Sustain. Sci.* **2023**, *18*, 1939–1960. [CrossRef] [PubMed]
2. Frank, E.G.; Schlenker, W. Balancing Economic and Ecological Goals. *Science* **2016**, *353*, 651–652. [CrossRef] [PubMed]
3. Huang, J.; Tang, Z.; Liu, D.; He, J. Ecological Response to Urban Development in a Changing Socio-Economic and Climate Context: Policy Implications for Balancing Regional Development and Habitat Conservation. *Land Use Policy* **2020**, *97*, 104772. [CrossRef]
4. Yang, R.; Chen, H.; Chen, S.; Ye, Y. Spatiotemporal Evolution and Prediction of Land Use/Land Cover Changes and Ecosystem Service Variation in the Yellow River Basin, China. *Ecol. Indic.* **2022**, *145*, 109579. [CrossRef]
5. Jiang, B.; Chen, Y.; Xiao, Y.; Zhao, J.; Ouyang, Z. Evaluation of the Economic Value of Final Ecosystem Services from the Baiyangdian Wetland. *Acta Ecol. Sin.* **2017**, *37*, 2497–2505. [CrossRef]
6. Garrick, D.; Siebentritt, M.A.; Aylward, B.; Bauer, C.J.; Purkey, A. Water Markets and Freshwater Ecosystem Services: Policy Reform and Implementation in the Columbia and Murray-Darling Basins. *Ecol. Econ.* **2009**, *69*, 366–379. [CrossRef]
7. Xue, D.; Wang, Z.; Li, Y.; Liu, M.; Wei, H. Assessment of Ecosystem Services Supply and Demand (Mis) Matches for Urban Ecological Management: A Case Study in the Zhengzhou–Kaifeng–Luoyang Cities. *Remote Sens.* **2022**, *14*, 1703. [CrossRef]
8. Zadehdabagh, N.; Monavari, S.M.; Kargari, N.; Taghavi, L.; Pirasteh, S. Sustainability of Agroecosystems by Indices: A Comparative Study between Indicators of Ecological Footprint Sustainability and Emergy Analysis; a Case Study in Dez Catchment, Iran. *Ecol. Model.* **2022**, *474*, 110165. [CrossRef]
9. Zhang, S.; Wang, Y.; Wang, Y.; Li, Z.; Hou, Y. Spatiotemporal Evolution and Influencing Mechanisms of Ecosystem Service Value in the Tarim River Basin, Northwest China. *Remote Sens.* **2023**, *15*, 591. [CrossRef]
10. Costanza, R.; d'Arge, R.; De Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'neill, R.V.; Paruelo, J. The Value of the World's Ecosystem Services and Natural Capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
11. Xie, G.D.; Zhang, C.X.; Zhang, C.S.; Xiao, Y.; Lu, C.X. The Value of Ecosystem Services in China. *Resour. Sci.* **2015**, *37*, 1740–1746.
12. Wu, C.; Chen, B.; Huang, X.; Wei, Y.D. Effect of Land-Use Change and Optimization on the Ecosystem Service Values of Jiangsu Province, China. *Ecol. Indic.* **2020**, *117*, 106507. [CrossRef]
13. Li, N.; Wang, J.; Wang, H.; Fu, B.; Chen, J.; He, W. Impacts of Land Use Change on Ecosystem Service Value in Lijiang River Basin, China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 46100–46115. [CrossRef] [PubMed]

14. Yang, J.; Xie, B.; Zhang, D. Spatial–Temporal Evolution of ESV and Its Response to Land Use Change in the Yellow River Basin, China. *Sci. Rep.* **2022**, *12*, 13103. [CrossRef] [PubMed]
15. Zhao, X.; Yi, P.; Xia, J.; He, W.; Gao, X. Temporal and Spatial Analysis of the Ecosystem Service Values in the Three Gorges Reservoir Area of China Based on Land Use Change. *Environ. Sci. Pollut. Res.* **2022**, *29*, 26549–26563. [CrossRef] [PubMed]
16. Wang, B.; Hu, C.; Zhang, Y. Multi-Scenario Simulation of the Impact of Land Use Change on the Ecosystem Service Value in the Suzhou-Wuxi-Changzhou Metropolitan Area, China. *Chin. Geogr. Sci.* **2024**, *34*, 79–92. [CrossRef]
17. Na, L.; Zhao, Y.; Feng, C.-C.; Guo, L. Regional Ecological Risk Assessment Based on Multi-Scenario Simulation of Land Use Changes and Ecosystem Service Values in Inner Mongolia, China. *Ecol. Indic.* **2023**, *155*, 111013. [CrossRef]
18. Zhang, X.; Zhou, Y.; Long, L.; Hu, P.; Huang, M.; Xie, W.; Chen, Y.; Chen, X. Simulation of Land Use Trends and Assessment of Scale Effects on Ecosystem Service Values in the Huaihe River Basin, China. *Environ. Sci. Pollut. Res.* **2023**, *30*, 58630–58653. [CrossRef] [PubMed]
19. Cai, G.; Xiong, J.; Wen, L.; Weng, A.; Lin, Y.; Li, B. Predicting the Ecosystem Service Values and Constructing Ecological Security Patterns in Future Changing Land Use Patterns. *Ecol. Indic.* **2023**, *154*, 110787. [CrossRef]
20. Cao, Y.; Wang, C.; Su, Y.; Duan, H.; Wu, X.; Lu, R.; Su, Q.; Wu, Y.; Chu, Z. Study on Spatiotemporal Evolution and Driving Forces of Habitat Quality in the Basin along the Yangtze River in Anhui Province Based on InVEST Model. *Land* **2023**, *12*, 1092. [CrossRef]
21. Chen, Y.; Zhao, L.; Tao, J.; Zhang, P. Habitat Quality Evaluation before and after Unused Land Development Based on InVEST Model: A Case Study of Tang County. *Chin. J. Eco-Agric.* **2020**, *28*, 1093–1102.
22. Xiao, P.; Zhou, Y.; Li, M.; Xu, J. Spatiotemporal Patterns of Habitat Quality and Its Topographic Gradient Effects of Hubei Province Based on the InVEST Model. *Environ. Dev. Sustain.* **2023**, *25*, 6419–6448. [CrossRef]
23. Zhu, C.; Zhang, X.; Zhou, M.; He, S.; Gan, M.; Yang, L.; Wang, K. Impacts of Urbanization and Landscape Pattern on Habitat Quality Using OLS and GWR Models in Hangzhou, China. *Ecol. Indic.* **2020**, *117*, 106654. [CrossRef]
24. Zhang, X.; Liao, L.; Xu, Z.; Zhang, J.; Chi, M.; Lan, S.; Gan, Q. Interactive Effects on Habitat Quality Using InVEST and GeoDetector Models in Wenzhou, China. *Land* **2022**, *11*, 630. [CrossRef]
25. He, N.; Guo, W.; Wang, H.; Yu, L.; Cheng, S.; Huang, L.; Jiao, X.; Chen, W.; Zhou, H. Temporal and Spatial Variations in Landscape Habitat Quality under Multiple Land-Use/Land-Cover Scenarios Based on the PLUS-InVEST Model in the Yangtze River Basin, China. *Land* **2023**, *12*, 1338. [CrossRef]
26. Hu, N.; Xu, D.; Zou, N.; Fan, S.; Wang, P.; Li, Y. Multi-Scenario Simulations of Land Use and Habitat Quality Based on a PLUS-InVEST Model: A Case Study of Baoding, China. *Sustainability* **2023**, *15*, 557. [CrossRef]
27. Liu, Y.; Qu, B.; Jiang, E.; Hao, L.; Zhu, Y.; Jing, Y. Allocating Payments for Ecosystem Services under Future Multiple Scenarios in the Yellow River Basin, China. *Ecol. Indic.* **2023**, *157*, 111232. [CrossRef]
28. Su, Y.; Ma, X.; Feng, Q.; Liu, W.; Zhu, M.; Niu, J.; Liu, G.; Shi, L. Patterns and Controls of Ecosystem Service Values under Different Land-Use Change Scenarios in a Mining-Dominated Basin of Northern China. *Ecol. Indic.* **2023**, *151*, 110321. [CrossRef]
29. Li, X.; Liu, Z.; Li, S.; Li, Y. Multi-Scenario Simulation Analysis of Land Use Impacts on Habitat Quality in Tianjin Based on the PLUS Model Coupled with the InVEST Model. *Sustainability* **2022**, *14*, 6923. [CrossRef]
30. Zhang, S.; Zhong, Q.; Cheng, D.; Xu, C.; Chang, Y.; Lin, Y.; Li, B. Landscape Ecological Risk Projection Based on the PLUS Model under the Localized Shared Socioeconomic Pathways in the Fujian Delta Region. *Ecol. Indic.* **2022**, *136*, 108642. [CrossRef]
31. 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]
32. He, N.; Zhou, Y.; Wang, L.; Li, Q.; Zuo, Q.; Liu, J. Spatiotemporal Differentiation and the Coupling Analysis of Ecosystem Service Value with Land Use Change in Hubei Province, China. *Ecol. Indic.* **2022**, *145*, 109693. [CrossRef]
33. Zhang, X.; Song, W.; Lang, Y.; Feng, X.; Yuan, Q.; Wang, J. Land Use Changes in the Coastal Zone of China's Hebei Province and the Corresponding Impacts on Habitat Quality. *Land Use Policy* **2020**, *99*, 104957. [CrossRef]
34. Nie, Y.; Zhang, X.; Yang, Y.; Liu, Z.; He, C.; Chen, X.; Lu, T. Assessing the Impacts of Historical and Future Land-Use/Cover Change on Habitat Quality in the Urbanizing Lhasa River Basin on the Tibetan Plateau. *Ecol. Indic.* **2023**, *148*, 110147. [CrossRef]
35. Lohse, K.A.; Newburn, D.A.; Opperman, J.J.; Merenlender, A.M. Forecasting Relative Impacts of Land Use on Anadromous Fish Habitat to Guide Conservation Planning. *Ecol. Appl.* **2008**, *18*, 467–482. [CrossRef] [PubMed]
36. Wei, Q.; Abudureheman, M.; Halike, A.; Yao, K.; Yao, L.; Tang, H.; Tuheti, B. Temporal and Spatial Variation Analysis of Habitat Quality on the PLUS-InVEST Model for Ebinur Lake Basin, China. *Ecol. Indic.* **2022**, *145*, 109632. [CrossRef]
37. Xie, L.; Wang, H.; Liu, S. The Ecosystem Service Values Simulation and Driving Force Analysis Based on Land Use/Land Cover: A Case Study in Inland Rivers in Arid Areas of the Aksu River Basin, China. *Ecol. Indic.* **2022**, *138*, 108828. [CrossRef]
38. He, J.; Huang, J.; Li, C. The Evaluation for the Impact of Land Use Change on Habitat Quality: A Joint Contribution of Cellular Automata Scenario Simulation and Habitat Quality Assessment Model. *Ecol. Model.* **2017**, *366*, 58–67. [CrossRef]
39. Wang, P.; Li, R.; Liu, D.; Wu, Y. Dynamic Characteristics and Responses of Ecosystem Services under Land Use/Land Cover Change Scenarios in the Huangshui River Basin, China. *Ecol. Indic.* **2022**, *144*, 109539. [CrossRef]
40. Wang, B.; Oguchi, T.; Liang, X. Evaluating Future Habitat Quality Responding to Land Use Change under Different City Compaction Scenarios in Southern China. *Cities* **2023**, *140*, 104410. [CrossRef]
41. Yin, Z.; Feng, Q.; Zhu, R.; Wang, L.; Chen, Z.; Fang, C.; Lu, R. Analysis and Prediction of the Impact of Land Use/Cover Change on Ecosystem Services Value in Gansu Province, China. *Ecol. Indic.* **2023**, *154*, 110868. [CrossRef]

42. Song, W.; Deng, X. Land-Use/Land-Cover Change and Ecosystem Service Provision in China. *Sci. Total Environ.* **2017**, *576*, 705–719. [CrossRef]
43. Shirmohammadi, B.; Malekian, A.; Salajegheh, A.; Taheri, B.; Azarnivand, H.; Malek, Z.; Verburg, P.H. Scenario Analysis for Integrated Water Resources Management under Future Land Use Change in the Urmia Lake Region, Iran. *Land Use Policy* **2020**, *90*, 104299. [CrossRef]
44. Sang, L.; Zhang, C.; Yang, J.; Zhu, D.; Yun, W. Simulation of Land Use Spatial Pattern of Towns and Villages Based on CA–Markov Model. *Math. Comput. Model.* **2011**, *54*, 938–943. [CrossRef]
45. Liu, X.; Liang, X.; Li, X.; Xu, X.; Ou, J.; Chen, Y.; Li, S.; Wang, S.; Pei, F. A Future Land Use Simulation Model (FLUS) for Simulating Multiple Land Use Scenarios by Coupling Human and Natural Effects. *Landsc. Urban Plan.* **2017**, *168*, 94–116. [CrossRef]
46. Fang, C. China's Urban Agglomeration and Metropolitan Area Construction under the New Development Pattern. *Econ. Geogr.* **2021**, *41*, 1–7.
47. Lin, X.; Xu, M.; Cao, C.; P. Singh, R.; Chen, W.; Ju, H. Land-Use/Land-Cover Changes and Their Influence on the Ecosystem in Chengdu City, China during the Period of 1992–2018. *Sustainability* **2018**, *10*, 3580. [CrossRef]
48. Zhang, L.; Peng, W.; Zhang, J. Assessment of Land Ecological Security from 2000 to 2020 in the Chengdu Plain Region of China. *Land* **2023**, *12*, 1448. [CrossRef]
49. Li, Y.; Zhan, J.; Zhang, F.; Zhang, M.; Chen, D. The Study on Ecological Sustainable Development in Chengdu. *Phys. Chem. Earth Parts A/B/C* **2017**, *101*, 112–120. [CrossRef]
50. He, J.; Hu, S. Ecological Efficiency and Its Determining Factors in an Urban Agglomeration in China: The Chengdu-Chongqing Urban Agglomeration. *Urban Clim.* **2022**, *41*, 101071. [CrossRef]
51. Liang, X.; Guan, Q.; Clarke, K.C.; Liu, S.; Wang, B.; Yao, Y. Understanding the Drivers of Sustainable Land Expansion Using a Patch-Generating Land Use Simulation (PLUS) Model: A Case Study in Wuhan, China. *Comput. Environ. Urban Syst.* **2021**, *85*, 101569. [CrossRef]
52. Gao, L.; Tao, F.; Liu, R.; Wang, Z.; Leng, H.; Zhou, T. Multi-Scenario Simulation and Ecological Risk Analysis of Land Use Based on the PLUS Model: A Case Study of Nanjing. *Sustain. Cities Soc.* **2022**, *85*, 104055. [CrossRef]
53. Huang, X.; Liu, J.; Peng, S.; Huang, B. The Impact of Multi-Scenario Land Use Change on the Water Conservation in Central Yunnan Urban Agglomeration, China. *Ecol. Indic.* **2023**, *147*, 109922. [CrossRef]
54. Zhang, S.; Yang, P.; Xia, J.; Wang, W.; Cai, W.; Chen, N.; Hu, S.; Luo, X.; Li, J.; Zhan, C. Land Use/Land Cover Prediction and Analysis of the Middle Reaches of the Yangtze River under Different Scenarios. *Sci. Total Environ.* **2022**, *833*, 155238. [CrossRef] [PubMed]
55. Wang, Z.; Zeng, J.; Chen, W. Impact of Urban Expansion on Carbon Storage under Multi-Scenario Simulations in Wuhan, China. *Environ. Sci. Pollut. Res.* **2022**, *29*, 45507–45526. [CrossRef]
56. Luo, S.; Hu, X.; Sun, Y.; Yan, C.; Zhang, X. Multi-Scenario Land Use Change and Its Impact on Carbon Storage Based on Coupled Plus-Invest Model. *Chin. J. Eco-Agric.* **2023**, *31*, 300–314.
57. Nie, W.; Xu, B.; Ma, S.; Yang, F.; Shi, Y.; Liu, B.; Hao, N.; Wu, R.; Lin, W.; Bao, Z. Coupling an Ecological Network with Multi-Scenario Land Use Simulation: An Ecological Spatial Constraint Approach. *Remote Sens.* **2022**, *14*, 6099. [CrossRef]
58. Chen, W.; Wang, G.; Gu, T.; Fang, C.; Pan, S.; Zeng, J.; Wu, J. Simulating the Impact of Urban Expansion on Ecosystem Services in Chinese Urban Agglomerations: A Multi-Scenario Perspective. *Environ. Impact Assess. Rev.* **2023**, *103*, 107275. [CrossRef]
59. Song, W.; Cao, S.; Du, M.; Lu, L. Distinctive Roles of Land-Use Efficiency in Sustainable Development Goals: An Investigation of Trade-Offs and Synergies in China. *J. Clean. Prod.* **2023**, *382*, 134889. [CrossRef]
60. Yu, B.; Zang, Y.; Wu, C.; Zhao, Z. Spatiotemporal Dynamics of Wetlands and Their Future Multi-Scenario Simulation in the Yellow River Delta, China. *J. Environ. Manag.* **2024**, *353*, 120193. [CrossRef]
61. Li, Y.; Yao, S.; Jiang, H.; Wang, H.; Ran, Q.; Gao, X.; Ding, X.; Ge, D. Spatial-Temporal Evolution and Prediction of Carbon Storage: An Integrated Framework Based on the MOP–PLUS–InVEST Model and an Applied Case Study in Hangzhou, East China. *Land* **2022**, *11*, 2213. [CrossRef]
62. Lei, J.; Chen, Y.; Li, L.; Chen, Z.; Chen, X.; Wu, T.; Li, Y. Spatiotemporal Change of Habitat Quality in Hainan Island of China Based on Changes in Land Use. *Ecol. Indic.* **2022**, *145*, 109707. [CrossRef]
63. Tang, J.; Zhou, L.; Dang, X.; Hu, F.; Yuan, B.; Yuan, Z.; Wei, L. Impacts and Predictions of Urban Expansion on Habitat Quality in the Densely Populated Areas: A Case Study of the Yellow River Basin, China. *Ecol. Indic.* **2023**, *151*, 110320. [CrossRef]
64. 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]
65. Li, Y.; Li, Y.; Zhou, Y.; Shi, Y.; Zhu, X. Investigation of a Coupling Model of Coordination between Urbanization and the Environment. *J. Environ. Manag.* **2012**, *98*, 127–133. [CrossRef]
66. Yang, C.; Zeng, W.; Yang, X. Coupling Coordination Evaluation and Sustainable Development Pattern of Geo-Ecological Environment and Urbanization in Chongqing Municipality, China. *Sustain. Cities Soc.* **2020**, *61*, 102271. [CrossRef]
67. Meng, B.; Wang, X.; Zhang, Z.; Huang, P. Spatio-Temporal Pattern and Driving Force Evolution of Cultivated Land Occupied by Urban Expansion in the Chengdu Metropolitan Area. *Land* **2022**, *11*, 1458. [CrossRef]
68. Wang, A.; Liao, X.; Tong, Z.; Du, W.; Zhang, J.; Liu, X.; Liu, M. Spatial-Temporal Dynamic Evaluation of the Ecosystem Service Value from the Perspective of "Production-Living-Ecological" Spaces: A Case Study in Dongliao River Basin, China. *J. Clean. Prod.* **2022**, *333*, 130218. [CrossRef]

69. Yuan, Y.; Chen, D.; Wu, S.; Mo, L.; Tong, G.; Yan, D. Urban Sprawl Decreases the Value of Ecosystem Services and Intensifies the Supply Scarcity of Ecosystem Services in China. *Sci. Total Environ.* **2019**, *697*, 134170. [CrossRef]
70. Zeng, C.; Liu, Y.; Stein, A.; Jiao, L. Characterization and Spatial Modeling of Urban Sprawl in the Wuhan Metropolitan Area, China. *Int. J. Appl. Earth Obs. Geoinf.* **2015**, *34*, 10–24. [CrossRef]
71. Yang, Y. Evolution of Habitat Quality and Association with Land-Use Changes in Mountainous Areas: A Case Study of the Taihang Mountains in Hebei Province, China. *Ecol. Indic.* **2021**, *129*, 107967. [CrossRef]
72. Li, T.; Bao, R.; Li, L.; Tang, M.; Deng, H. Temporal and Spatial Changes of Habitat Quality and Their Potential Driving Factors in Southwest China. *Land* **2023**, *12*, 346. [CrossRef]
73. Hu, J.; Zhang, J.; Li, Y. Exploring the Spatial and Temporal Driving Mechanisms of Landscape Patterns on Habitat Quality in a City Undergoing Rapid Urbanization Based on GTWR and MGWR: The Case of Nanjing, China. *Ecol. Indic.* **2022**, *143*, 109333. [CrossRef]
74. Yang, X.; Yang, W.; Li, Y.; Hu, B. Land Use Land Cover Change Analysis after the Earthquake of Wenchuan. In Proceedings of the 2010 International Conference on Multimedia Technology, Ningbo, China, 29–31 October 2010; IEEE: Piscataway, NJ, USA, 2010; pp. 1–4.
75. Fangbo, L.; Yanting, Z. Measurement and Spatial Difference Analysis of Innovation-Driven Urban Development Levels in Sichuan Province. *Contemp. Soc. Sci.* **2022**, *2022*, 13.
76. Xiao, Y.; Li, Y.; Huang, H. Conflict or Coordination? Assessment of Coordinated Development between Socioeconomic and Ecological Environment in Resource-Based Cities: Evidence from Sichuan Province of China. *Environ. Sci. Pollut. Res.* **2021**, *28*, 66327–66339. [CrossRef]
77. Zhao, Y.; He, L.; Bai, W.; He, Z.; Luo, F.; Wang, Z. Prediction of Ecological Security Patterns Based on Urban Expansion: A Case Study of Chengdu. *Ecol. Indic.* **2024**, *158*, 111467. [CrossRef]
78. Sichuan Provincial People's Government S.P.P.G. Six Major Areas with 50 Measures! Striving for More "Chengdu Blue". Available online: https://www.sc.gov.cn/10462/11857/13305/13370/2023/4/4/964775e514af47a7ab8baafabeef4172.shtml (accessed on 7 March 2024).
79. Zhao, S.; Da, L.; Tang, Z.; Fang, H.; Song, K.; Fang, J. Ecological Consequences of Rapid Urban Expansion: Shanghai, China. *Front. Ecol. Environ.* **2006**, *4*, 341–346. [CrossRef]
80. Lin, Z. Ecological Urbanism in East Asia: A Comparative Assessment of Two Eco-Cities in Japan and China. *Landsc. Urban Plan.* **2018**, *179*, 90–102. [CrossRef]
81. Li, X.; Suoerdahan, G.; Shi, Z.; Xing, Z.; Ren, Y.; Yang, R. Spatial–Temporal Impacts of Urban Sprawl on Ecosystem Services: Implications for Urban Planning in the Process of Rapid Urbanization. *Land* **2021**, *10*, 1210. [CrossRef]
82. Li, W.; Zhou, W.; Bai, Y.; Pickett, S.T.; Han, L. The Smart Growth of Chinese Cities: Opportunities Offered by Vacant Land. *Land Degrad. Dev.* **2018**, *29*, 3512–3520. [CrossRef]
83. Xiong, C.; Zhang, Y.; Liu, X.; Luan, Q.; Wei, S. Urban Vacant Land in Rapidly Urbanized Areas: Status, Micro-Level Drivers, and Implications. *J. Chin. Gov.* **2021**, *6*, 554–577. [CrossRef]
84. Zhang, L.; Huang, L.; Xia, J.; Duan, K. Spatial-Temporal Evolution and Its Influencing Factors on Urban Land Use Efficiency in China's Yangtze River Economic Belt. *Land* **2022**, *12*, 76. [CrossRef]
85. Zhu, D.; Wang, Y.; Peng, S.; Zhang, F. Influence Mechanism of Polycentric Spatial Structure on Urban Land Use Efficiency: A Moderated Mediation Model. *Int. J. Environ. Res. Public Health* **2022**, *19*, 16478. [CrossRef] [PubMed]
86. Zhao, Q.; Wen, Z.; Chen, S.; Ding, S.; Zhang, M. Quantifying Land Use/Land Cover and Landscape Pattern Changes and Impacts on Ecosystem Services. *Int. J. Environ. Res. Public Health* **2020**, *17*, 126. [CrossRef] [PubMed]
87. Liu, J.; Hou, X.; Wang, Z.; Shen, Y. Study the Effect of Industrial Structure Optimization on Urban Land-Use Efficiency in China. *Land Use Policy* **2021**, *105*, 105390. [CrossRef]
88. Loo, B.P.; Comtois, C. *Sustainable Railway Futures: Issues and Challenges*; Routledge: London, UK, 2015.
89. Salahi Moghadam, A. A Multidimensional and Dynamic Analysis of Urban Spatial Structure: A Case-Study of the Sydney Metropolitan Area, 1981–2006. Ph.D. Thesis, UNSW Sydney, Kensington, Australia, 2013.
90. Rastvortseva, S.N.; Manaeva, I.V. Modern Development of Small and Medium-Sized Cities: Trends and Drivers. *Ekon. I Sotsialnye Peremeny* **2022**, *15*, 110–127. [CrossRef]
91. Wang, S.; Liu, Z.; Chen, Y.; Fang, C. Factors Influencing Ecosystem Services in the Pearl River Delta, China: Spatiotemporal Differentiation and Varying Importance. *Resour. Conserv. Recycl.* **2021**, *168*, 105477. [CrossRef]