diversity

MDPI

Article

Exploring the Relationship between Ecosystem Services and Sustainable Development Goals for Ecological Conservation: A Case Study in the Hehuang Valley of Qinghai-Tibet Plateau

Hejie Wei [1,†], Ke Wang [1,†], Yu Ma [1], Qingxiang Meng [1], Yi Yang [2,*] and Mengxue Liu [3]

[1] College of Resources and Environmental Sciences, Henan Agricultural University, Zhengzhou 450046, China; hjwei@henau.edu.cn (H.W.); wangke010603@163.com (K.W.); mayu99@henau.edu.cn (Y.M.); qxmeng@henau.edu.cn (Q.M.)
[2] College of Forestry, Henan Agricultural University, Zhengzhou 450046, China
[3] Lhasa Plateau Ecosystem Research Station, Key Laboratory of Ecosystem Network Observation and Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; mengxueliu@mail.bnu.edu.cn
* Correspondence: yangyi023@henau.edu.cn
† These authors contributed equally to this work.

Abstract: With the increase in human activities and the acceleration of urbanization, over-exploitation of natural resources has led to a decline in ecosystem services (ESs), subsequently affecting the achievement of sustainable development goals (SDGs). As the key ecological zone of Qinghai-Tibet Plateau, the stability and enhancement of ESs in the Hehuang Valley are crucial for achieving SDGs and biodiversity conservation. This study quantifies nine SDGs for the Hehuang Valley in the last twenty years. Four ecological models were utilized to compute key ESs: net primary productivity (NPP), water yield, soil retention, and sand fixation. Panel data were analyzed using a coupling coordination model to quantify the relationship between ESs and sustainable development level (SDL) in each county. Additionally, the Geographically and Temporally Weighted Regression (GTWR) model was employed to examine the correlation between ESs and SDL. The results indicate the following: (1) During the period, NPP and water yield first increased and then decreased. The capacity for soil retention and sand fixation showed an overall increase, highlighting substantial variability among counties in their ability to deliver these ESs. (2) The SDL of counties in the Hehuang Valley increased, with Xining City showing slightly higher SDL than other counties. (3) The overall coupling coordination degree among NPP, water yield, soil retention, sand fixation, and SDL in the Hehuang Valley exhibited an upward trend in the last twenty years. SDL demonstrated the highest coordination degree with NPP, followed by soil retention, water yield, and sand fixation. (4) Most counties in the Hehuang Valley exhibited a lag in SDL relative to NPP, water yield, and soil retention in the last twenty years. In the early stage, sand fixation and SDL were primarily lagging in SDL, while in the late stages, sand fixation lagged behind SDL. (5) During the period, there was an increasing negative correlation observed between the four ESs and SDL. The positive contribution of NPP and sand fixation in some counties gradually shifted to a negative effect, and the negative effect of water yield and soil retention on SDL intensified. The impact of human activities on ecosystem function hindered local SDL. This study offers scientific theoretical backing and practical recommendations for promoting SDL and biodiversity conservation in the Hehuang Valley.

Keywords: ecosystem services; sustainable development goals; coupling coordination model; GTWR model; Hehuang Valley

check for updates

Citation: Wei, H.; Wang, K.; Ma, Y.; Meng, Q.; Yang, Y.; Liu, M. Exploring the Relationship between Ecosystem Services and Sustainable Development Goals for Ecological Conservation: A Case Study in the Hehuang Valley of Qinghai-Tibet Plateau. *Diversity* **2024**, *16*, 553. https://doi.org/10.3390/d16090553

Academic Editor: Alfredo Ortega-Rubio

Received: 14 August 2024
Revised: 1 September 2024
Accepted: 3 September 2024
Published: 5 September 2024

1. Introduction

An ecosystem is a complex system influenced by various natural, economic, and social factors, and it undergoes dynamic changes over time [1]. The connotation of ecosystem services (ESs) is integral to the framework of sustainable development goals (SDGs) [2], exerting a significant influence on societal and economic sustainability. ESs function as a crucial link between natural contributions and human needs across various timeframes and geographic scales [3]. These services, which are essential functions of ecosystems, facilitate connections between natural and societal systems, playing a vital role in human well-being and progress. They contribute to the overall economic value of the earth [4] and serve as important indicators of ecological health in regions. In 2015, the United Nations' 193 member states adopted the 2030 Agenda for Sustainable Development, encompassing 17 SDGs and 169 associated targets [5]. These goals include various social, economic, and environmental objectives, each interacting with ESs in different ways [6]. The interactions and influencing factors among the SDGs are complex [7]. Many scholars have analyzed the synergies and trade-offs between SDGs [8], the prioritization of SDGs [9], and the factors influencing these goals [10]. Their findings suggest that achieving the SDGs requires proactive management of production activities to sustain livelihoods, create new job opportunities, build climate change resilience, and harmonize with environmental changes to provide robust ESs [11].

The attainment of SDGs depends on more than just social and economic progress; it also hinges on integrating ecological factors into sustainable development decisions [12]. ESs are pivotal in shaping the SDGs [13], and the primary aim of implementing ecological conservation measures is to promote regional sustainability. It is crucial to evaluate the contribution of these measures to sustainable development. The protection, restoration, and sustainable provision of ESs are crucial for attaining the SDGs [5]. Connecting ESs with the SDGs fosters synergistic development across various aspects of sustainable development [14]. ESs can serve as direct indicators of ecosystem functions and quantitatively demonstrate the direct or indirect contributions of ecosystems to SDGs from an ecological perspective [15]. For instance, provisioning services contribute to the attainment of SDG2 (Zero Hunger), SDG3 (Good Health and Well-being), and SDG6 (Clean Water and Sanitation), among others. ESs are closely related to SDG15 (Life on Land), SDG13 (Climate Action), SDG14 (Life Below Water), and SDG6, indirectly promoting the realization of 13 other goals [16]. Zhang et al. [17] conducted an analysis using SDG 15.3.1 and carbon storage as metrics to assess the impact of land use changes on ecosystem service values, providing valuable insights for improving land degradation. Wood et al. [18] identified the importance of ESs in achieving the 2030 SDGs by integrating the perspectives of researchers through the "ecosystem service-goal" contribution framework. The results of their survey indicated that 16 ESs were considered to contribute to 41 targets within 12 SDGs. Other researchers have conducted global analyses on the relationships between multiple ESs provided by urban landscapes and SDGs, finding that 17 different ESs are linked to 12 SDGs [19].

Currently, numerous scholars have utilized various methodologies to examine the complex relationships and impacts between ESs and sustainable development level (SDL). Hussain et al. [20] employed an interpretive structural model to investigate the factors influencing sustainable tourism development and their inherent logical connections. Xu et al. [12] applied the geographical detector method to analyze the cumulative effects of ESs and urbanization on achieving SDGs from a spatial perspective. Liu et al. [7] utilized a panel data model to analyze the contribution of protected areas to SDGs, thereby providing a theoretical foundation for the management of protected areas and regional SDL. Yin et al. [21], through downscaled localized SDG indicators, regression methods, and mechanism analysis, identified the contributions of ecosystem carbon sequestration services to SDGs, revealing significant progress in resource and environmental sustainability goals on the Loess Plateau. Additionally, some scholars conducted expert surveys to scrutinize the global-scale relationships between distinct ESs and SDGs [22].

The coupling coordination model comprehensively considers the interactions and coordination mechanisms among different factors, quantitatively assessing their contributions [23]. It can also adapt variables to actual conditions to accommodate changes across various temporal and spatial scales [24]. Consequently, it facilitates a more comprehensive and accurate understanding of the coupling relationship between ESs and SDGs, offering optimization and coordination recommendations to achieve equilibrium and mutual benefit. For instance, He et al. [25] scrutinized the coupling coordination relationship between water resource and eco-environment in China. Yang et al. [26] employed the coupling coordination index to reveal the temporal-spatial coupling relationship between ESs and human well-being, thereby promoting the SDL of urban agglomerations. Yang et al. [27] assessed the SDL status of land ecology in Shanxi Province using ecological footprint and coupling coordination degree (CCD) as indicators. By integrating the two indicators into a mathematical model using the TOPSIS multi-criteria decision-making approach, they obtained comprehensive scores for the SDL of land ecology in various cities in Shanxi Province. This outlines the temporal-spatial changes in SDL and ESs.

Although the coupling coordination model quantifies the relationship between ESs and SDGs, it does not indicate the correlation between the two, which is a more specific type of relationship [28]. The explanation of how ES trends affect the attainment of SDGs and the regional variability in this impact remains incomplete [29]. Recognizing the relationship between ESs and SDGs is vital for policymaking and pinpointing current management requirements [30]. Thus, employing the Geographically and Temporally Weighted Regression (GTWR) model to analyze this relationship can yield valuable insights into its extent.

The Hehuang Valley, situated at the transition zone between the Qinghai-Tibet Plateau and the Loess Plateau, occupies a unique geographical position and serves as a "sensitive area" for ecology and climate in Asia [31]. It is a relatively low-altitude region of the Qinghai-Tibet Plateau, suitable for human habitation, and is also economically significant in Qinghai Province [32]. As population and socio-economic growth continue, the interconnection between humans and nature becomes increasingly tight [33]. The pursuit of a better quality of life and improved well-being is a pressing need for people. However, intensified human activities and environmental degradation pose serious threats to ESs. Evaluating the results at smaller administrative units, particularly at the county level, is more targeted and can effectively assess SDGs, thereby promoting their implementation [30]. Additionally, in line with ongoing urbanization, Qinghai Province plans to establish the Xining-Haidong metropolitan area, with a focus on the economic development of Xining and Haidong. The unique geography and environment of the Hehuang Valley, along with its future development potential, will significantly impact its ecosystems and ecological environment [34]. Therefore, exploring the coupling relationship between ESs and SDGs in the Hehuang Valley can provide scientific support for policymaking and resource management, thereby promoting the effective coupling and synergistic development of ESs and SDGs.

With this context in mind, this study aims to achieve the following objectives: (1) Create a unique evaluation framework for SDL and ESs tailored to local conditions using available data, and assess the SDL and ESs status of the Hehuang Valley quantitatively; (2) Investigate the interconnection between key ESs and SDL by coupling model; (3) Employ the GTWR model to uncover the temporal and spatial relationships between various types of ESs and SDL.

2. Materials and Methods

2.1. Study Area

Situated at the transition zone between the Qinghai-Tibet Plateau and the Loess Plateau, the Hehuang Valley (35°~38° N, 100°~103° E) serves as a significant agricultural region of the Qinghai-Tibet Plateau [35] (Figure 1). It functions as the political, economic, and cultural center of Qinghai Province [36]. Spanning an area of approximately 35,273.77 km^2, the valley plays a crucial role in ensuring food security for Qinghai Province and the wider Qinghai-Tibet Plateau [35]. Despite occupying only 5% of the province's total area, it accommodates approximately 72.77% of the province's population and 60% of its arable land. The valley consists of broad river valleys and well-developed terraces, with elevations ranging from 1650 to 2400 m, making it suitable for agricultural practices. Wheat, corn, soybeans, rapeseed, and other crops are cultivated in this region [37]. The Hehuang Valley includes 17 counties and districts, including Chengdong, Chengzhong, Chengxi, and Chengbei districts et al., in Xining City; Ledu District and Ping'an District et al., in Haidong City; Jianzha County and Tongren County in Huangnan; Menyuan County in Haibei; and Guide County in Hainan.

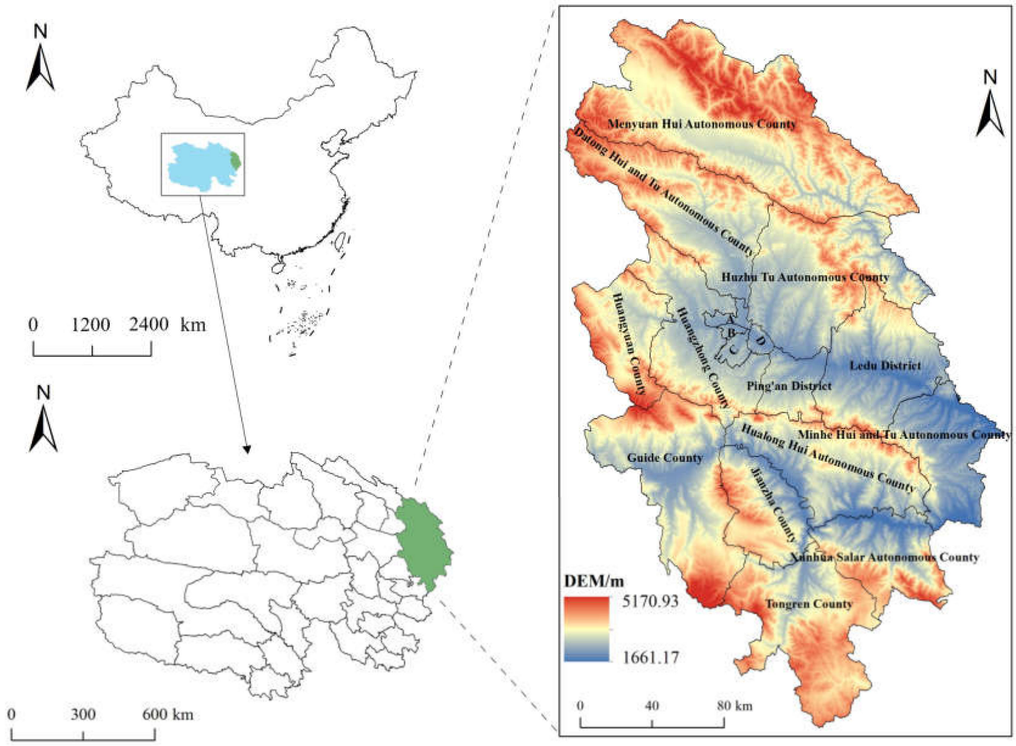

Figure 1. Location of the Hehuang Valley. Note: A represents Chengbei District; B represents Chengxi District; C represents Chengzhong District; D represents Chengdong District.

In 2020, the population of the Hehuang Valley was 1.38 million. The per capita regional GDP reached 64,537 yuan, and the per capita total retail sales of consumer goods was 13,282 yuan. The total grain and total meat output in the Hehuang Valley were 1.038 million tons and 271,000 tons, respectively, representing increases of 47.3% and 58.5% compared to the year 2000 [34]. The valley's geomorphological types include river valley areas, shallow mountainous areas, and hilly areas, with annual precipitation ranging from 166.4 to 646.6 mm, mostly occurring from May to October, coinciding with the warm season [38]. The region experiences a typical highland continental climate with distinct seasonal variations. The Hehuang Valley has been significantly uplifted due to the block movements of the Qilian Mountains. The parallel ridge-valley system of the Yemanan Mountains—Shule South Mountains (Shule Mountains), Datong Mountains, and Dabanshan Mountains—and the upper Danghe River Valley—Hala Lake, Qinghai Lake, and Huangshui Valley—extend into this area. Additionally, the remaining ridges of Dabanshan, Laji Mountain, and Xiqing Mountain enclose the Yellow River and Huangshui Valleys, forming the "three mountains enclosing two valleys" geomorphological framework of the region [34]. Grassland and forestland were the main land use types of Hehuang Valley and the construction land has increased significantly in the context of urbanization (Figure 2).

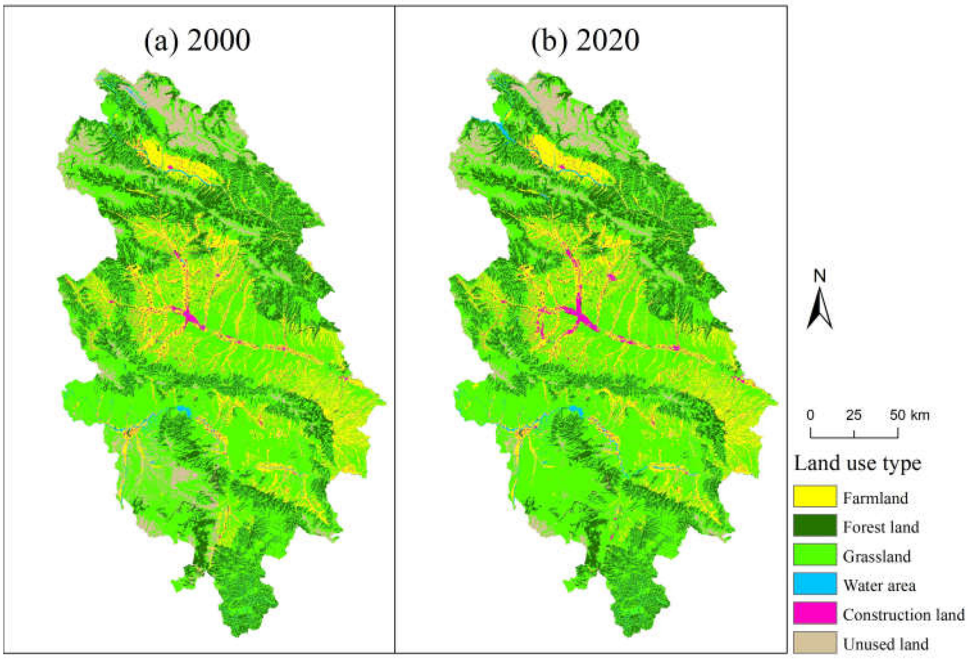

Figure 2. Land Use Status of the Hehuang Valley in 2000 (**a**) and 2020 (**b**).

2.2. Data Sources

The data employed in this study consist mainly of natural geographic information, socio-economic statistics, and land use-related data. Specific data usage and sources are detailed in Table 1. Additional data such as regional GDP, fixed asset investment, retail sales, average years of education, mortality rate, employment rate, broadband access, fixed telephone users, local fiscal expenditure, number of industrial enterprises, hospital bed numbers, public library collections, and sports venues are sourced from the Qinghai Statistical Yearbook, China County Statistical Yearbook, National Economic and Social Development Statistical Bulletin, Xining Statistical Yearbook, China City Statistical Yearbook, and China Health Statistics Yearbook.

Table 1. Data Sources and Their Uses.

Data Name	Data Format	Data Source	Data Use
DEM Elevation Data	Raster data with 30 m resolution	http://www.gscloud.cn/search, accessed on 10 February 2023	Basic parameter input for soil retention and wind erosion model
Land Use Remote Sensing Data	Raster data with 30 m resolution	http://www.resdc.cn/, accessed on 22 December 2023	Basic parameter input for NPP, water yield, and soil retention models
MOD13Q1	Raster data with 250 m resolution	https://www.nasa.gov/, accessed on 11 January 2024	Obtain Normalized Difference Vegetation Index (NDVI) and vegetation coverage data
Global Land Cover Data (China subset)	Raster data with 100 m resolution	http://bdc.casnw.net/yyzc/sj/250299.shtml, accessed on 13 December 2023	Obtain vegetation-type data for the study area
ERA5-Land Wind Speed Data	List data	www.ecmwf.int, accessed on 10 December 2023	Obtain wind factor and cumulative time distribution raster maps for various wind speed levels

Table 1. *Cont.*

Data Name	Data Format	Data Source	Data Use
Soil Moisture Data	Raster data with 1000 m resolution	http://bdc.casnw.net/yyzc/sj/250299.shtml, accessed on 1 December 2023	Topsoil moisture factor (0–10 cm depth range)
Monthly Precipitation Data	List data	http://data.cma.cn/, accessed on 18 November 2023	Obtain rainfall erosion factor and annual average rainfall raster maps
Soil Texture, Organic Matter, Depth	Raster data with 1000 m resolution	http://bdc.casnw.net/yyzc/sj/250299.shtml, accessed on 12 December 2023	Basic parameter input for water yield and soil retention models
Monthly Temperature, Precipitation, Radiation Data	List data	http://data.cma.cn/, accessed on 16 November 2023	Obtain monthly average temperature, radiation raster data, and annual potential evaporation data
Annual Meat, Grain Production, and Population Data	Statistical data	Qinghai Statistical Yearbook, China County Statistical Yearbook	Obtain grain and meat production and county population data
Road Network Data	Vector data	http://www.resdc.cn/, accessed on 8 December 2023	Obtain road and railway data for 1995, 2012, and 2020
2020 Standard Map of China	Vector data	Ministry of Natural Resources (https://www.mnr.gov.cn/, accessed on 25 December 2023)	Obtain map with approval number GS(2020)4619 and county vector data
PM2.5 Data	Statistical data	https://quotsoft.net/air/, accessed on 10 September 2023	Obtain PM2.5 data for various periods across counties

2.3. Technical Route

The research methodology and approach in this study are outlined in Figure 3. Firstly, utilizing the Carnegie-Ames-Stanford Approach (CASA), the Integrated Valuation of ESs and Tradeoffs (InVEST) model's water yield module, the Revised Universal Soil Loss Equation (RUSLE), and a wind erosion model, four key ESs were quantified: net primary productivity (NPP), water yield, soil retention, and sand fixation. Secondly, SDL was assessed across three dimensions: foundational, developmental acceleration, and environmental aspects. The entropy weight method and linear weighting method were applied to calculate these dimensions and the overall SDL for 17 counties in the Hehuang Valley for the years 2000, 2010, and 2020. Thirdly, a coupling coordination model was employed to determine the degree of coordination and coupling between SDL and ESs. Additionally, a relative development model was utilized to analyze the development level relative to ESs and SDL. Finally, the Geographically and Temporally Weighted Regression (GTWR) model was utilized to compute correlation coefficients between SDL and ESs. This approach helped to elucidate their temporal and spatial interaction mechanisms.

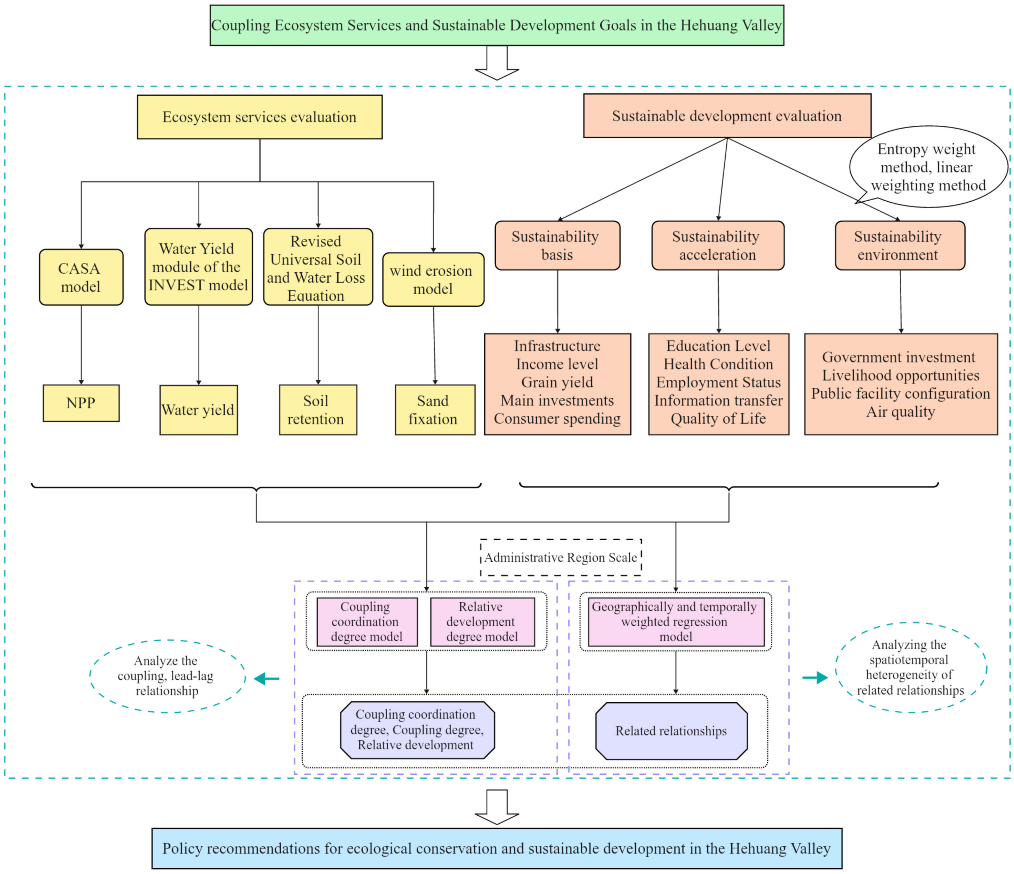

Figure 3. Technical Route of the Study.

2.4. Ecosystem Service Assessment Methods

2.4.1. Selection Basis for Ecosystem Service Indicators

Based on the Millennium Ecosystem Assessment, there are more than 20 ESs, which are divided into provisioning services, regulating services, supporting services, and cultural services. Considering the feasibility of the method, the importance of ESs, and the local physical geographical features, this study selects four ESs—NPP, water yield, soil retention, and sand fixation—to examine changes in ESs in the Hehuang Valley. The detailed illustrations are as follows. NPP, as an indicator of the capacity of vegetation communities to produce organic matter in their natural environment, is of particular importance in an agricultural area like the Hehuang Valley. Analyzing the temporal and spatial variations of NPP will provide insights into the carbon cycle and its support capacity for local agricultural production. The Hehuang Valley, being located in arid and semi-arid regions, has a high demand for water. Therefore, investigating changes in water yield will enable the analysis of the ecosystem's ability to supply water resources, which can guide the formulation of effective water resource protection policies. The complex terrain combined with a dry climate and concentrated precipitation in the Hehuang Valley results in severe soil erosion. The area's location as a transition zone makes it susceptible to natural disasters such as sandstorms, which have a remarkable impact on the local ecosystem and the livelihoods of residents. Studying the temporal and spatial changes in sand fixation will provide valuable insights into the ecosystem's ability to defend against wind and sand disasters, thereby supporting sand disaster prevention and ecological environment improvement efforts. Moreover, four ESs all belong to the regulating services or supporting services, but no provisioning services or cultural services are chosen. Firstly, because provisioning services and cultural services are terminal services, the relationship between them and SDGs is relatively direct and clear. However, regulating services and supporting services are basic functions that affect the quality of provisioning services and cultural services, and the relationship between them and SDGs is relatively complex. Current research has not yet clarified this, which is a knowledge gap. Secondly, indicators related to provisioning services and cultural services are reflected in the sustainable development indicator system, such as grain output, education, etc.

2.4.2. Measurement of Net Primary Productivity, Water Yield, and Soil Retention

NPP was estimated by utilizing the CASA model based on the principle of light energy utilization. The detailed model and parameter selection were based on Zhu et al. [39]. Water yield was assessed by the Water Yield module of the InVEST model [40] based on the principle of water balance. This assessment takes into account factors such as topography, vegetation type, meteorology, and soil texture to achieve spatialization of water yield. The RUSLE is used to quantify soil erosion in the Hehuang Valley. Soil retention is determined by the difference between potential soil erosion and actual soil erosion [41,42].

2.4.3. Measurement of Sand Fixation

This study utilizes the wind erosion model established by Li et al. [43], which includes wind erosion modulus calculation models for three types of underlying surfaces: cultivated land, grassland/shrubland, and sandy land. The wind erosion model assesses the sand fixation capability of the ecosystem by subtracting the actual wind erosion modulus from the potential wind erosion modulus.

2.5. Sustainable Development Assessment Methods

Based on the SDGs, relevant research [44,45], and local conditions, the sustainable development indicator system was established considering three dimensions: sustainable development foundation, sustainable development acceleration, and sustainable development environment. This study ultimately selected nine SDGs and 17 influencing indicators to analyze the SDL and construct the SDL evaluation indicator system (Table 2).

Table 2. SDL Evaluation Indicator System for the Hehuang Valley.

Dimension	Factor	Indicator Level	Indicator	Weight	SDG Indicator
Sustainability Foundation	Capital Status	Infrastructure	Road network density	0.024	Sustainable Cities and Communities (SDG 11)
		Income Level	Regional GDP	0.095	No Poverty (SDG 1)
		Grain Output	Total grain production	0.065	Zero Hunger (SDG 2)
	Capital Change	Major Investment	Total fixed asset investment	0.113	Sustainable Cities and Communities (SDG 11)
		Consumer Spending	Total retail sales of consumer goods	0.132	Responsible Consumption and Production (SDG 12)
Sustainability Acceleration	Quality Status	Education Level	Average years of schooling	0.012	Quality Education (SDG 4)
		Health Status	Mortality rate	0.015	Good Health and Well-being (SDG 3)
	Skill Level	Employment Status	Employment rate	0.008	Decent Work and Economic Growth (SDG 8)
	Living Standard	Information Transmission	Broadband access	0.125	Industry, Innovation, and Infrastructure (SDG 9)
			Fixed Telephone Users	0.063	Industry, Innovation, and Infrastructure (SDG 9)
		Quality of Life	Per capita total meat production	0.029	Zero Hunger (SDG 2)

Table 2. *Cont.*

Dimension	Factor	Indicator Level	Indicator	Weight	SDG Indicator
Sustainability Environment	Soft Environment	Government Investment	Local fiscal general budget expenditure	0.067	Sustainable Cities and Communities (SDG 11)
		Livelihood Opportunities	Number of industrial enterprises above designated size	0.034	Industry, Innovation, and Infrastructure (SDG 9)
	Hard Environment	Public Facility Allocation	Number of hospital beds	0.061	Good Health and Well-being (SDG 3)
			Total collection of public libraries	0.120	Quality Education (SDG 4)
			Number of sports venues	0.021	Good Health and Well-being (SDG 3)
		Air Quality	Average PM2.5	0.015	Climate Action (SDG 13)

The sustainable development foundation includes capital status and capital changes [30,46,47], involving SDG1, SDG2, SDG11, and SDG12. For capital status and changes, five indicators were selected to represent the foundational conditions required for SDL: infrastructure, income levels, grain output, major investments, and consumer spending. Sustainable acceleration [30,46,47] involves quality conditions, skill levels, and living standards, representing the achievement of SDG2, SDG3, SDG4, SDG8, and SDG9. Five indicators were selected to represent the acceleration conditions required for SDL: education levels, health status, employment status, information dissemination, and quality of life. As the main actors in SDL, people determine the direction and pace of sustainable development. A well-educated population facilitates faster and better SDL [30,48]. The sustainable development environment was classified into two categories: soft and hard environments, which represent the processes involved in achieving SDG3, SDG4, SDG9, SDG11, and SDG13. Four key indicators were selected to represent the necessary environmental conditions for SDL: government investment, livelihood opportunities, public facility allocation, and air quality.

To ensure comparability across different indicators, data normalization was necessary, thereby distributing the data within the range of [0, 1]. The objective weights of the indicators were then calculated using the entropy weight method. Based on the SDL Evaluation Indicator System established in Table 2 for the Hehuang Valley, in combination with the entropy weight method, we computed the sustainability foundation, sustainability acceleration, sustainability environment, and overall SDL evaluation indices for the years 2000, 2010, and 2020.

2.6. Quantification of the Coupling Relationship between ESs and SDL

The coupling degree between NPP, water yield, soil retention, sand fixation, and SDL reflects the extent of their interaction and the developmental changes between them. The CCD indicates the level of coordination between the two systems. A higher CCD indicates a more harmonious relationship between SDL and ESs. The calculation formulas are as follows:

$$T = aG_i + bF(x) \tag{1}$$

$$C = \left\{ G_i \times F(x) / [G_i \times F(x)/2]^2 \right\}^k \tag{2}$$

$$D = \sqrt{T \times C} \tag{3}$$

where $F(x)$ is the SDL index, and G_i (i = 1, 2, 3, 4) are the standardized values of NPP, water yield, soil retention, and sand fixation, respectively. T is the comprehensive evaluation value of SDL and ESs, C is the coupling degree, and D is the CCD, ranging between [0, 1]. Since both systems are equally important, $a = b = 0.5$ and there are $k = 2$ system layers. Referring to related research [49], the CCD is classified into five types: severe imbalance (0.0–0.2), moderate imbalance (0.2–0.4), basic coordination (0.4–0.6), moderate coordination (0.6–0.8), and high coordination (0.8–1.0), as shown in Table 3.

Table 3. Classification Standards for Coupling Degree and CCD between ESs and SDL in the Hehuang Valley.

Coupling Degree *C* Value	Coupling Type	CCD *D* Value	Coordination Type
$0 \leq C \leq 0.3$	Low-level coupling	$0 \leq D < 0.2$	Severe imbalance
$0.3 < C \leq 0.5$	Antagonistic phase	$0.2 \leq D < 0.4$	Moderate imbalance
$0.5 < C \leq 0.8$	Running-in phase	$0.4 \leq D < 0.6$	Basic coordination
$0.8 < C \leq 1$	High-level coupling	$0.6 \leq D < 0.8$	Moderate coordination
——	——	$0.8 \leq D < 1$	High coordination

To further analyze the relationship between ESs and SDL in each county, the relative development degree of both factors was calculated. Based on previous research findings [34], all counties in the study area were classified into three types: ESs-lagging type, synchronous development type of ESs and SDL, and SDL-lagging type. The specific classification standards can be found in Table 4.

Table 4. Classification Standards for Relative Development Types of ESs and SDL in the Hehuang Valley.

Type	Relative Development Degree	Specific Classification
Relative Development Types	$0 < \beta = Gi/F(x) < 0.85$	ESs-lagging type
	$0.85 < \beta = Gi/F(x) < 1.25$	Synchronous development type
	$\beta = Gi/F(x) > 1.25$	SDL-lagging type

Note: G_i (i = 1, 2, 3, 4) are the standardized values of NPP, water yield, soil retention, and sand fixation, respectively; $F(x)$ is the SDL index.

2.7. GTWR Regression Model

The coupling coordination model and the relative development model identified the coupling coordination and leading-lagging relationship between individual ESs and SDL. However, due to the complexity of ESs and the trade-offs/synergies within them, it is necessary to simultaneously explore the relationship between all four ESs and SDL. Therefore, we further used the GTWR model, treating the four services as independent variables and SDL as the dependent variable, to comprehensively explore the spatiotemporal relationship between ESs and SDL.

The GTWR model introduces a temporal dimension to the traditional Geographically Weighted Regression (GWR) model [50], analyzing the influence mechanisms between variables from both temporal and spatial perspectives, thereby revealing the heterogeneity of variables over time and space. Thus, the GTWR model is employed to study the interaction between ESs and SDL. The specific formula [50] is as follows:

$$Y_{ik} = a_0(m_i, n_i, t_i) + \sum_{i=1}^{k} (m_i, n_i, t_i) X_{ik} + \varepsilon_i \tag{4}$$

where Y_{ik} is the SDL of county i at time k; $a_0(m_i, n_i, t_i)$ represents the geographical location; X_{ik} represents the ESs level of county i at time k; and ε_i is the random factor of county i at time k. This formula measures the correlation between ESs and SDL in county i at time k.

3. Results

3.1. Temporal and Spatial Changes in ESs and SDL in the Hehuang Valley

3.1.1. Changes in ESs

Figure 4 displays the temporal changes in ESs for each administrative unit in the Hehuang Valley from 2000 to 2020. Soil retention remained relatively stable, while NPP, water yield, and sand fixation exhibited more fluctuation, with both increases and decreases observed.

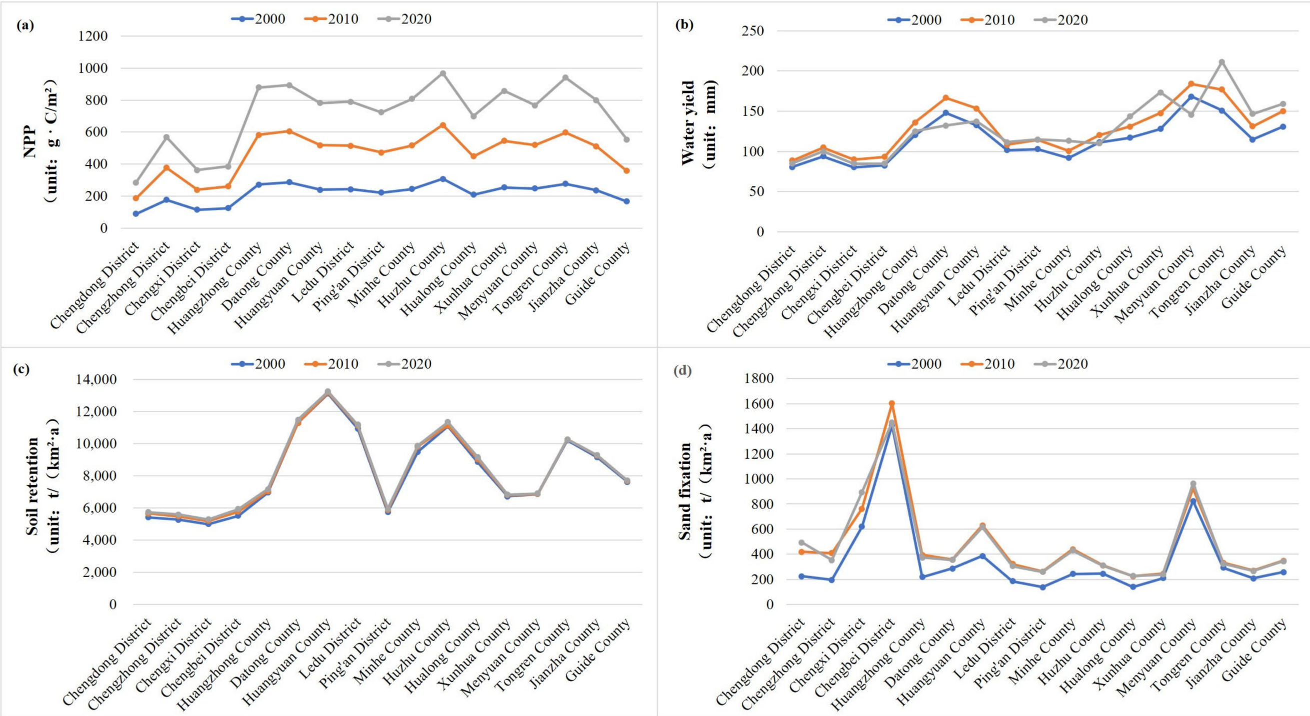

Figure 4. ES Changes in the County Scale of Hehuang Valley in 2000, 2010, and 2020, Including NPP (**a**), Water Yield (**b**), Soil Retention (**c**), and Sand Fixation (**d**).

Figure 4a reveals that between 2000 and 2010, NPP generally increased across all regions, with the most significant increase occurring in Huangzhong County, from 271.221 g·C/m^2 to 311.832 g·C/m^2, representing a net increase of 40.611 g·C/m^2. On the other hand, Chengdong District displayed the smallest increase, rising from 89.044 g·C/m^2 to 97.440 g·C/m^2, equivalent to a net increase of 8.396 g·C/m^2. However, comparing 2010 to 2020, NPP exhibited varying changes among the counties. Chengzhong District, Chengxi District, Chengbei District, Huangzhong County, Datong County, Huangyuan County, Ledu District, Ping'an District, Minhe County, Huzhu County, Hualong County, Xunhua County, and Menyuan County all experienced different degrees of decrease, with Datong County displaying the largest decrease of 30.656 g·C/m^2. In contrast, other regions showed slight increases, with Tongren County exhibiting the greatest growth from 320.044 g·C/m^2 to 343.439 g·C/m^2, representing a net increase of 23.394 g·C/m^2.

Figure 4b depicts the water yield changes, indicating that the overall change was not significant. However, when compared to 2010, several districts and counties experienced decreases in water yield, including Chengdong District, Chengzhong District, Chengxi District, Chengbei District, Huangzhong County, Datong County, Huangyuan County, Huzhu County, and Menyuan County. Of these, Menyuan County had the largest decrease, with a reduction of 38.272 mm. On the other hand, Tongren County exhibited the most substantial increase in water yield, rising from 150.749 mm to 211.542 mm, indicating a net increase of 60.793 mm.

Figure 4c illustrates the soil retention patterns, revealing no significant overall changes, as evidenced by the high overlap among the three curves. Huangyuan County consistently maintained the highest soil retention values in 2000, 2010, and 2020, with respective values of 13,131.574 t/(km^2·a), 13,185.213 t/(km^2·a), and 13,253.505 t/(km^2·a). On the other hand, Chengxi District consistently displayed the lowest soil retention values in the same years, with values of 5002.608 t/(km^2·a), 5185.912 t/(km^2·a), and 5283.454 t/(km^2·a), respectively.

Figure 4d portrays the changes in sand fixation, highlighting its instability over time. Chengbei District consistently exhibited the highest sand fixation values in 2000, 2010, and 2020, with respective values of 1425.845 t/(km^2·a), 1602.328 t/(km^2·a), and 1450.619 t/(km^2·a). Following closely was Menyuan County, with values of 823.514 t/(km^2·a), 924.560 t/(km^2·a), and 963.487 t/(km^2·a), respectively. Between 2000 and 2010, the overall sand fixation in the study area increased, primarily driven by Huangyuan County, which experienced a significant net increase of 243.346 t/(km^2·a). However, from 2010 to 2020, several districts and counties witnessed decreases in sand fixation, including Chengzhong District, Chengbei District, Huangzhong County, Datong County, Huangyuan County, Ledu District, Ping'an District, Minhe County, Huzhu County, Xunhua County, Tongren County, Jianzha County, and Guide County. Among them, Chengbei District reported the largest decrease of 151.709 t/(km^2·a). There was a notable increase in sand fixation in Chengdong District, indicating ongoing improvements in sand control in this area. Throughout the period from 2000 to 2020, Chengbei District and Menyuan County consistently exhibited the highest sand fixation values, demonstrating effective sand control in these regions.

In the grid scale, the average NPP in the Hehuang Valley increased from 246.40 g·C/m^2 to 273.68 g·C/m^2, representing a net increase of 27.28 g·C/m^2 from 2000 to 2020 (Figure 5). The average NPP values for 2000, 2010, and 2020 were 246.40 g·C/m^2, 277.23 g·C/m^2, and 273.68 g·C/m^2, respectively, indicating an initial increase followed by a decrease. The spatial distribution of NPP during this period remained largely consistent, with elevated values concentrated in the northeastern and southern regions of the Hehuang Valley. Conversely, lower NPP values were predominantly observed in the central and southwestern areas. Notably, the southern regions witnessed a significant increase in high NPP regions, while the northern regions experienced a rise in low NPP areas (Figure 5).

The average water yield in the Hehuang Valley increased from 131.09 mm to 142.27 mm, resulting in a net increase of 11.18 mm. The average water yield values for 2000, 2010, and 2020 were 131.09 mm, 146.84 mm, and 142.27 mm, respectively, indicating a similar trend of initial increase followed by a decrease. The spatial distribution of water yield exhibited a pattern centered around Xining City, with increasing values radiating outward. Higher water yield regions were mainly situated in the northern and southern parts of the Hehuang Valley, while lower water yield regions were observed in the central and northeastern regions. By 2020, the northern regions experienced a decrease in water yield compared to 2000, while the southern regions witnessed an increase. Moreover, while the overall spatial distribution of high and low water yield regions remained stable, the low-value areas expanded in 2020, primarily in the northern parts of the Hehuang Valley, compared to 2010. Additionally, the average soil retention in the Hehuang Valley increased from 8948.87 t/(km^2·a) to 9109.97 t/(km^2·a), representing a net increase of 161.10 t/(km^2·a). The average soil retention values for 2000, 2010, and 2020 were 8948.87 t/(km^2·a), 9030.82 t/(km^2·a), and 9109.97 t/(km^2·a), respectively, indicating an overall increase. The spatial distribution of soil retention exhibited a relatively scattered pattern, with high and low-value areas dispersed throughout. Higher soil retention areas were primarily concentrated in the northern-central regions, while lower soil retention areas were predominantly found in the northern regions. Overall, soil retention in the Hehuang Valley remained relatively low. The average sand fixation in the Hehuang Valley increased from 354.33 t/(km^2·a) to 457.41 t/(km^2·a), representing a net increase of 103.08 t/(km^2·a). The average sand fixation values for 2000, 2010, and 2020 were 354.33 t/(km^2·a), 456.96 t/(km^2·a), and 457.41 t/(km^2·a), respectively, indicating a gradual overall increase. The spatial distribution of sand fixation remained largely consistent over time, with high-value areas primarily located in the central and northern parts of the Hehuang Valley, while low-value areas were widespread throughout the region. The overall spatial distribution of high-value and low-value areas remained stable.

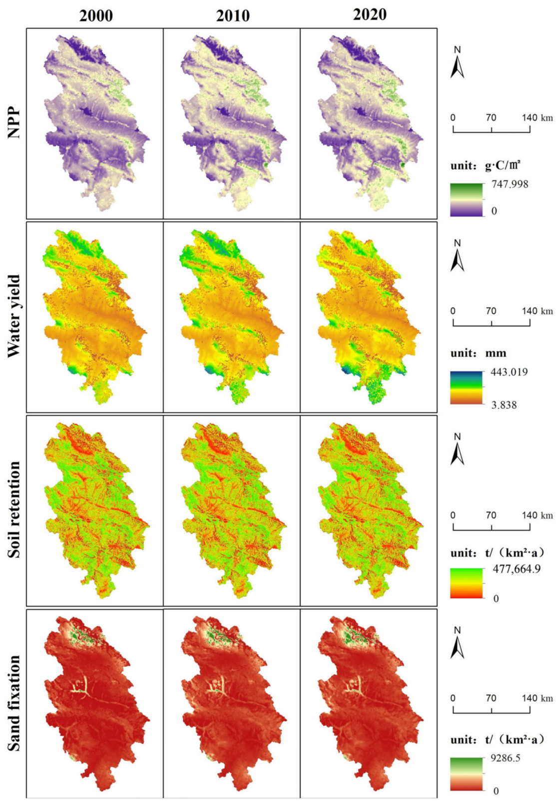

Figure 5. Spatiotemporal Distribution of ESs in the Grid Scale of Hehuang Valley from 2000 to 2020.

3.1.2. Changes in SDL

When examining the spatiotemporal changes in SDL (Figure 6), it is evident that the overall sustainability foundation and SDL increased across the 17 regions from 2000 to 2020. With the exception of Hualong County and Xunhua County, all other regions also experienced increases in sustainability acceleration scores and sustainability environment scores. High-value areas of SDL predominantly centered around the central part of the Hehuang Valley, radiating outward from Xining City. In contrast, low-value areas of SDL were primarily located in the southern part. Chengzhong District witnessed the most significant increase in sustainability foundation scores from 2010 to 2020, surpassing the increase recorded between 2000 and 2010. The scores rose from 0.062 in 2010 to 0.355 in 2020, reflecting a net increase of 0.293. Chengxi District followed closely, increasing from 0.075 in 2010 to 0.307 in 2020, resulting in a net increase of 0.232. On the other hand, Jianzhai County and Guide County observed marginal increases, both rising by 0.009. Chengxi District exhibited the most substantial increase in sustainability acceleration scores from 2010 to 2020, surpassing the increase observed between 2000 and 2010. The scores rose from 0.116 in 2010 to 0.218 in 2020, representing a net increase of 0.102. Chengbei District followed with a net increase of 0.097. While Hualong County experienced an initial increase in sustainability acceleration scores from 2000 to 2010, it subsequently declined, reducing by 0.018 in 2020 compared to 2010. Between 2000 and 2020, Chengxi District consistently achieved the highest sustainability environment scores, reaching 0.189 in 2020. From 2010 to 2020, all 17 regions witnessed increases in sustainability environment scores, although Xunhua County experienced a decrease of 0.015 between 2000 and 2010. Figure 6 illustrates the positive impact of the mentioned subsystems on the overall SDL. Notably, from 2010 to 2020, Chengxi District consistently achieved the highest SDL scores, witnessing a remarkable increase from 0.193 in 2000 to 0.713 in 2020. Chengzhong District followed suit, while Jianzhai County recorded the lowest score in 2020, measuring at 0.107. Notably, the overall SDL of all 17 counties in the Hehuang Valley demonstrated consistent growth from 2000 to 2020, reaching their peak values in 2020.

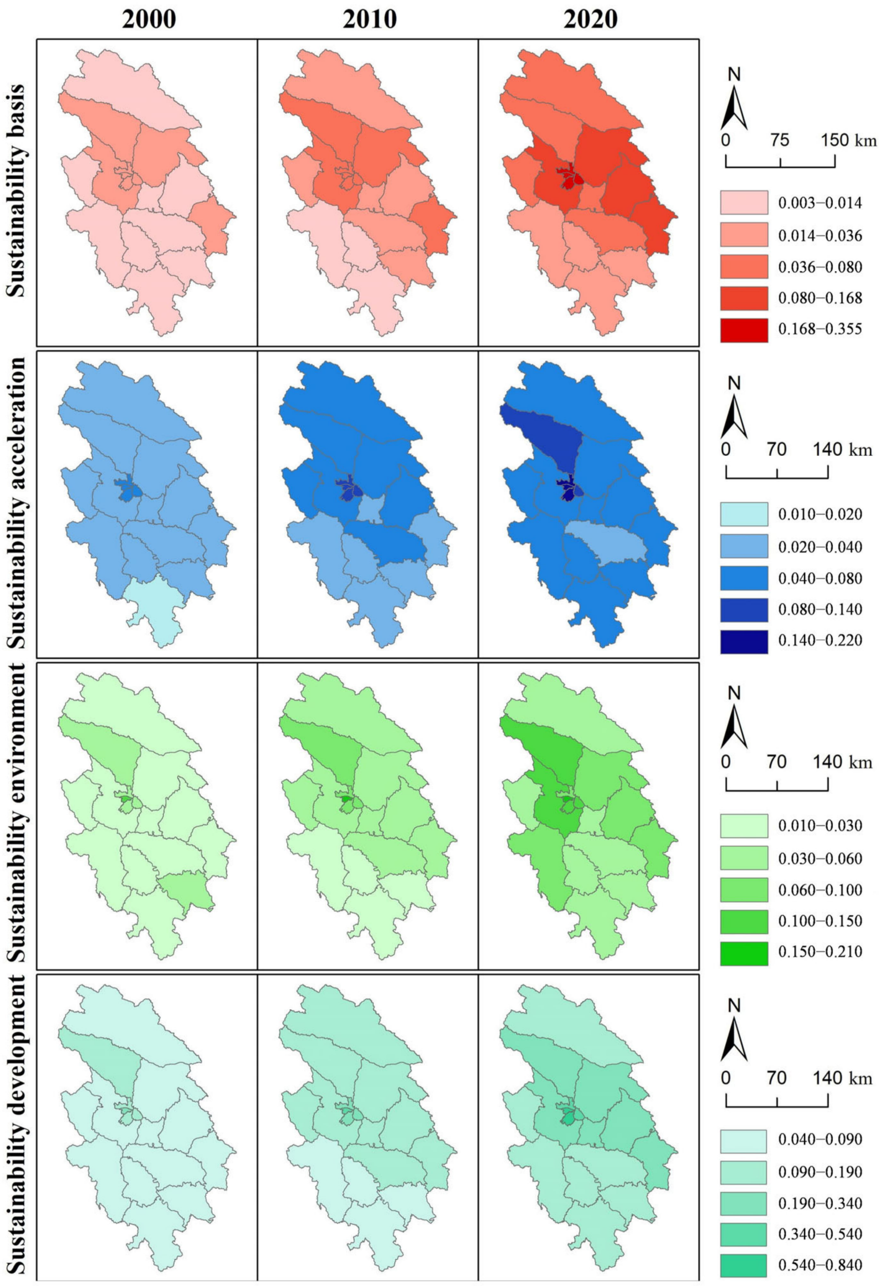

Figure 6. Spatiotemporal Distribution of SDL in the Counties of the Hehuang Valley from 2000 to 2020.

3.2. Coupling Coordination Analysis between ESs and SDL

3.2.1. Coupling Degree between ESs and SDL

Based on the spatiotemporal distribution of the coupling degree between ESs and SDL (Figure 7), it is evident that the coupling degree of all four ESs with SDL increased from 2000 to 2020.

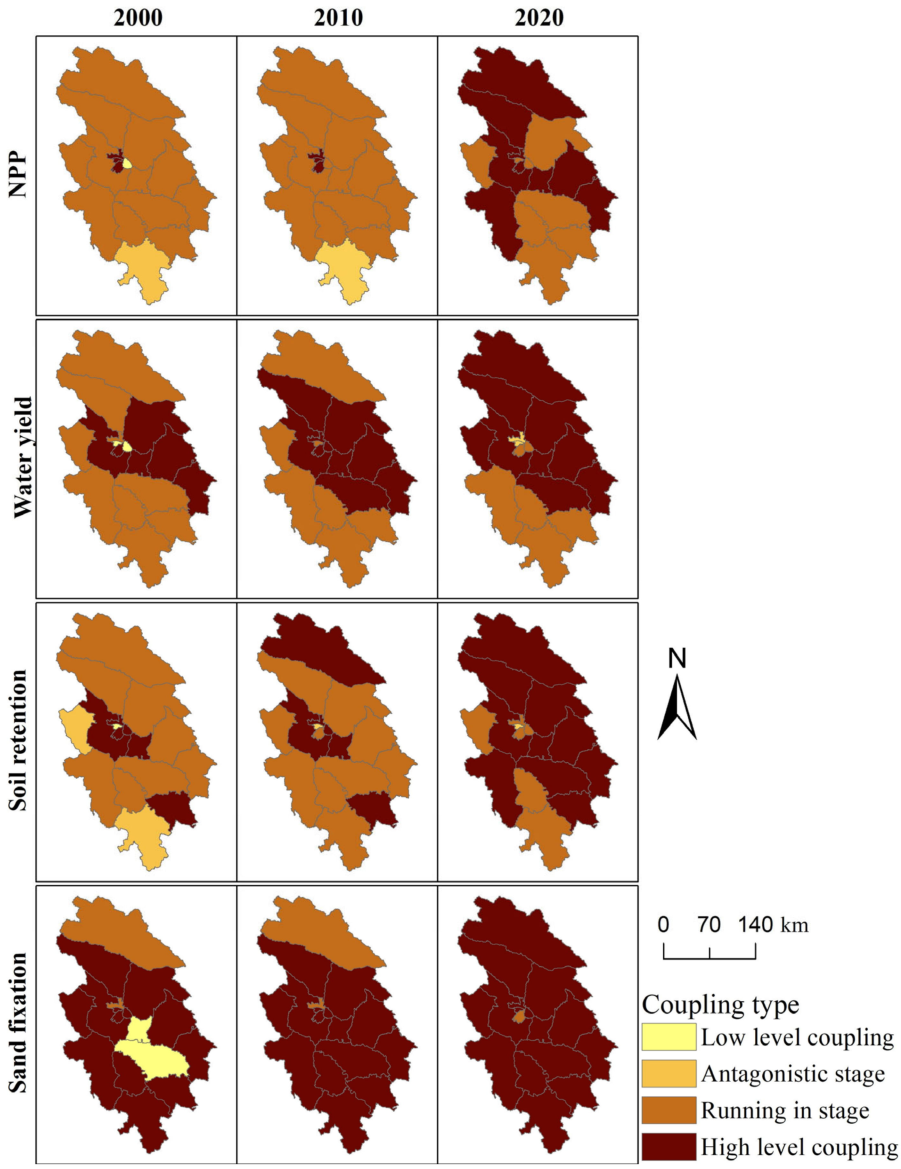

Figure 7. Spatiotemporal Distribution of the Coupling Degree between ESs and SDL in the Counties of the Hehuang Valley from 2000 to 2020.

In 2000, there was one county with a low-level coupling between NPP and SDL, and one county with a low-level coupling between soil retention and SDL. Additionally, two counties demonstrated a low-level coupling between water yield and SDL, while two other counties exhibited a low-level coupling between sand fixation and SDL. Between 2010 and 2020, all four types of ESs surpassed the antagonistic phase and progressed towards higher levels of coupling with SDL. By 2020, Ledu District and Huzhu County achieved a coupling degree value of 100% for water yield and SDL, Huangzhong County achieved the same for soil retention and SDL, and Guide County attained 100% for sand fixation and SDL. Notably, the coupling degree between water yield and SDL in Chengzhong District was 1 in 2000. However, this coupling degree continuously decreased from 2000 to 2020, suggesting a gradual divergence between water yield and SDL in this area.

3.2.2. CCD between ESs and SDL

Between 2000 and 2020, the overall CCD among NPP, water yield, soil retention, sand fixation, and SDL in the Hehuang Valley exhibited an upward trend (Figure 8). SDL demonstrated the highest coordination degree with NPP, followed by soil retention, water yield, and sand fixation.

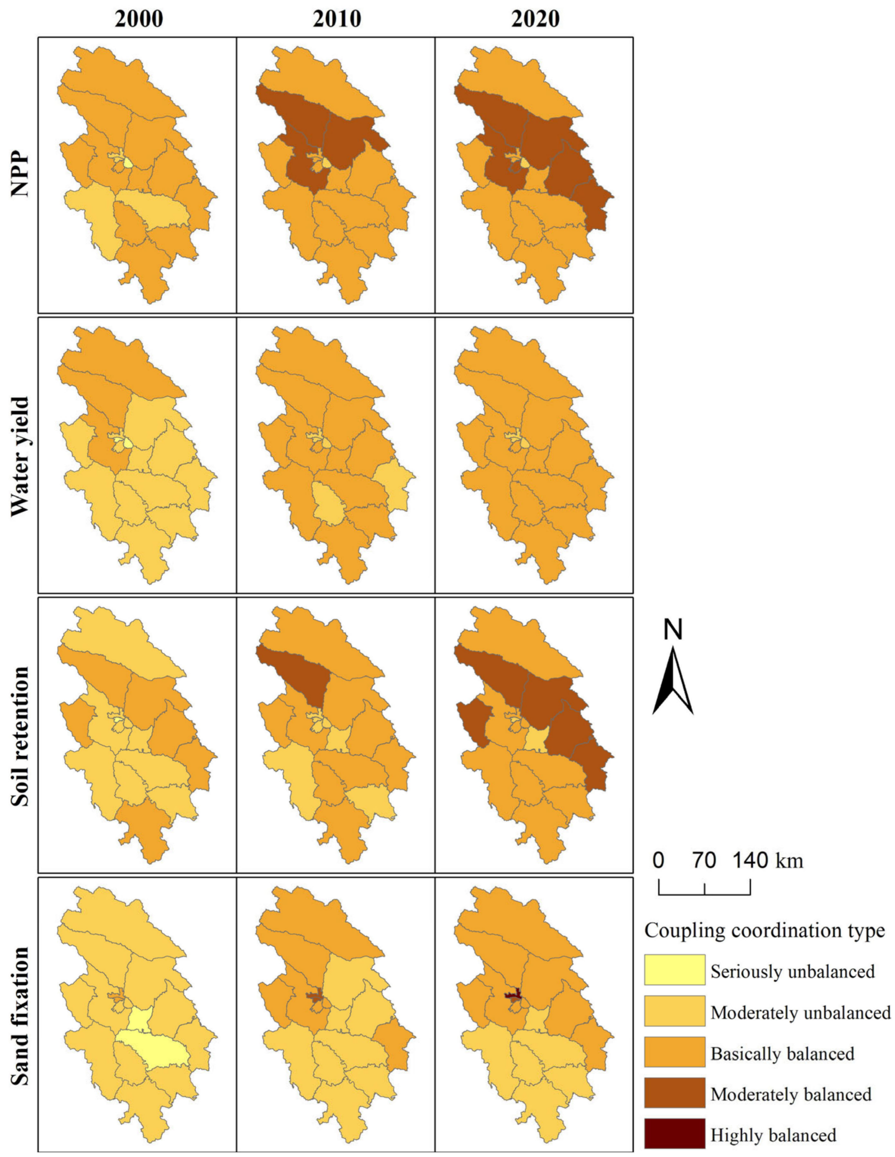

Figure 8. Spatiotemporal Distribution of the CCD between ESs and SDL in the Counties of the Hehuang Valley from 2000 to 2020.

The average CCD between NPP and SDL in the counties of the Hehuang Valley increased from 0.406 to 0.586, indicating a rise of 44.33%. The average CCDs for 2000, 2010, and 2020 were 0.406, 0.509, and 0.586, respectively, reflecting an overall increase. By 2020, the overall CCD between NPP and SDL reached basic to moderate coordination. Spatially, high-value areas were concentrated in the central and northern regions, while low-value areas were located in the northernmost and southern regions (Figure 8). Most counties achieved a state of basic coordination. From 2000 to 2020, the CCD increased in all 17 counties, with Chengdong District displaying the largest increase. The proportion of counties falling into the moderate coordination category rose from 0% to 35.29%.

From 2000 to 2020, there was a significant increase in the average CCD between water yield and SDL in the counties of the Hehuang Valley. Specifically, the degree increased from 0.321 to 0.496, representing a rise of 54.52%. The average CCDs for 2000, 2010, and 2020 were 0.321, 0.444, and 0.496, respectively, indicating an overall increase over the two-decade period. By 2020, the overall CCD between water yield and SDL reached the basic coordination stage. Spatially, only Chengbei District, Chengdong District, and Chengxi District were categorized as having moderate imbalance, while the remaining cities were in the basic coordination stage. Notably, from 2000 to 2020, the CCD increased in all 17 counties, with Chengxi District demonstrating the largest increase. Additionally, the proportion of counties in the basic coordination category saw a significant increase, rising from 17.65% in 2000 to 82.35% in 2020.

There was an increase in the average CCD between soil retention and SDL in the counties of the Hehuang Valley from 2000 to 2020. The degree rose from 0.358 to 0.516, resulting in a 44.13% increase. The average CCDs for 2000, 2010, and 2020 were 0.358, 0.439, and 0.516, respectively, showing an overall upward trend. By 2020, the overall CCD between soil retention and SDL reached the basic coordination stage. Spatially, Chengxi District and Ping'an District were categorized as having moderate imbalance, whereas Huangyuan County, Datong County, Huzhu County, Ledu District, and Minhe County were in the moderate coordination stage. The remaining cities were in the basic coordination stage. Similar to the water yield analysis, the CCD for soil retention increased in all 17 counties, with Chengxi District experiencing the largest increase. Furthermore, the proportion of counties in the basic coordination or higher category rose significantly, increasing from 35.29% in 2000 to 88.24% in 2020.

From 2000 to 2020, there was a remarkable increase in the average CCD between sand fixation and SDL in the counties of the Hehuang Valley. Specifically, the average CCD rose from 0.276 in 2000 to 0.467 in 2020, representing a 69.20% increase. The overall trend showed a consistent increase, with the average CCDs in 2010 and 2020 being 0.402 and 0.467, respectively. By 2020, half of the regions achieved a basic coordination level between sand fixation and SDL. Regarding the spatial distribution, Chengbei District was categorized as being in the high coordination stage, while Chengxi District was in the moderate coordination stage. Basic coordination was predominantly concentrated in the central and northern regions, whereas moderate imbalance was concentrated in the southern regions. It is noteworthy that the CCD increased in all 17 counties from 2000 to 2020, with Ping'an District showing the largest increase. Furthermore, the proportion of counties in the basic coordination or higher category rose significantly from 0% to 64.71%.

3.2.3. Relative Development Degree of ESs and SDL

From 2000 to 2020, the relative development types between NPP and SDL in the counties of the Hehuang Valley were predominantly SDL-lagging types (Figure 9). The SDL-lagging counties were widespread, with all counties except Chengzhong District, Chengxi District, Chengdong District, and Chengbei District belonging to this type. The number of NPP-lagging counties increased from 2 to 4.

The relative development types between water yield and SDL were also mainly SDL-lagging types (Figure 9). In 2000, all counties except those in Xining City belonged to the SDL-lagging type. By 2010, Minhe County transitioned from the SDL-lagging type to the synchronized development type, while Chengzhong District shifted from the synchronized development type to the water yield-lagging type. Compared to 2010, in 2020, Huangzhong County, Huzhu County, and Ledu District transitioned from the SDL-lagging type to the synchronized development type.

The relative development types between soil retention and SDL were predominantly SDL-lagging types (Figure 9). In 2000, all counties except those in Xining City belonged to the SDL-lagging type. By 2010, Ping'an District transitioned from the SDL-lagging type to the synchronized development type. Compared to 2000, in 2020, Huangzhong County transitioned from the SDL-lagging type to the synchronized development type, while Ping'an District transitioned from the SDL-lagging type to the soil retention-lagging type.

The relative development types between sand fixation and SDL showed significant changes. From 2000 to 2010, the predominant type was SDL-lagging; from 2010 to 2020, it shifted to sand fixation-lagging (Figure 9). From 2000 to 2020, the proportion of counties in the SDL-lagging type decreased from 35.29% to 17.65%, while the sand fixation-lagging type increased from 41.18% to 70.59%. The number of synchronized development counties decreased from 5 to 2.

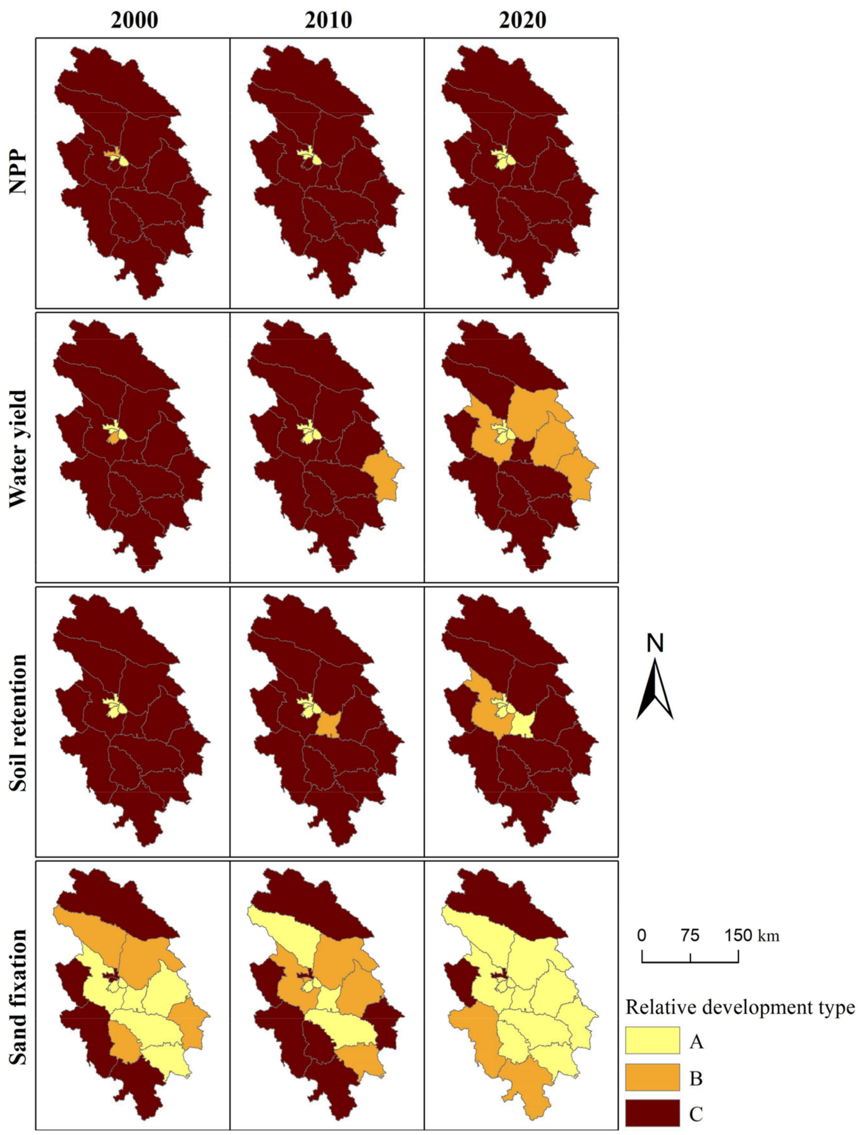

Figure 9. Spatiotemporal Distribution of the Relative Development Degree between ESs and SDL in the Counties of the Hehuang Valley from 2000 to 2020. Note: (A) Represents ESs-lagging type; (B) Represents synchronized development of ESs and SDL; (C) Represents SDL-lagging type.

3.3. Spatiotemporal Relationships between ESs and SDL

Multicollinearity among independent variables can affect regression analysis results [51]. Therefore, SPSS 26.0 software was used for multicollinearity diagnostics among the variables. The tests (Table 5) showed that the variance inflation factors (VIF) for all variables were less than 10 and the tolerances were greater than 0.1, indicating no multicollinearity.

Table 5. Multicollinearity Test.

Explanatory Variable	NPP	Water Yield	Soil Retention	Sand Fixation
VIF	3.012	1.830	1.766	1.251
Tolerance	0.332	0.546	0.566	0.799

Using ArcGIS 10.8.1 software, standardized values of the four ESs were used as explanatory variables, and the total SDL score was used as the dependent variable. GTWR models, GWR models, temporally weighted regression (TWR) models, and ordinary least squares (OLS) models were analyzed. The results (Table 6) indicate that the GTWR model generally had a higher R^2, lower AICc, and lower RSS [52].

Table 6. Comparison of GTWR, GWR, TWR, and OLS Models.

	GTWR	GWR	TWR	OLS
R^2	0.851	0.378	0.761	0.278
AICc	−57.095	−48.807	−89.523	−61.354
RSS	0.155	0.648	0.249	0.737
Adjusted R^2	0.838	0.324	0.740	——

Hence, the GTWR model was employed in this study to explore the correlation between the four ESs and SDL in 2000, 2010, and 2020, visualizing the spatial heterogeneity between ESs and SDL. This model is highly explanatory and effectively elucidates the relationship between ESs and SDL. Lower AICc values indicate better model fit [53].

Based on the parameter results of the GTWR model, correlation coefficients between ESs and SDL in the counties of the Hehuang Valley for 2000, 2010, and 2020 were obtained. These coefficients were categorized into six types: high negative, medium negative, low negative, low positive, medium positive, and high positive. Overall, the correlation between the four ESs and SDL has shown varying degrees of shift towards negative correlation over time (Figure 10).

As illustrated in Figure 10, from 2000 to 2020, there were significant changes in the correlation between NPP and SDL in the central and northern regions of our site. The negative correlation areas expanded, and the intensity of the negative correlation strengthened. By 2020, Menyuan County exhibited a high negative correlation. The central-southern regions, such as Guide County, Jianzha County, Tongren County, and Xunhua County showed medium positive correlations.

The correlation between water yield and SDL exhibited a continuous negative trend, with the degree of negative correlation intensifying. In 2000, except for Menyuan County, 16 regions showed medium negative correlations. By 2020, 12 regions exhibited high negative correlations, accounting for 70.59% of the Hehuang Valley.

The correlation between soil retention and SDL improved in Minhe County, shifting from a medium negative to a low negative correlation. However, the negative correlation intensified in Datong County and Huzhu County. From 2010 to 2020, the negative correlation between Minhe County and Menyuan County intensified, although Menyuan County maintained a low positive correlation. The remaining regions exhibited medium negative correlations.

The relationship between sand fixation and SDL in the 17 study areas in the Hehuang Valley exhibited varying degrees of positive correlation. Specifically, Tongren County, Minhe County, and Xunhua County showed high positive correlations in 2010. Significant efforts were made in the Hehuang Valley to enhance the environment and ensure sustainable sand control, thereby contributing to SDL. Between 2010 and 2020, the positive correlation in the central-southern regions increased, while in the central-northern regions, the positive correlation weakened. In fact, some areas even shifted from medium positive to medium negative correlation, such as Huangyuan County. Moreover, the number of regions with medium negative correlation rose from zero in 2000 to three in 2020.

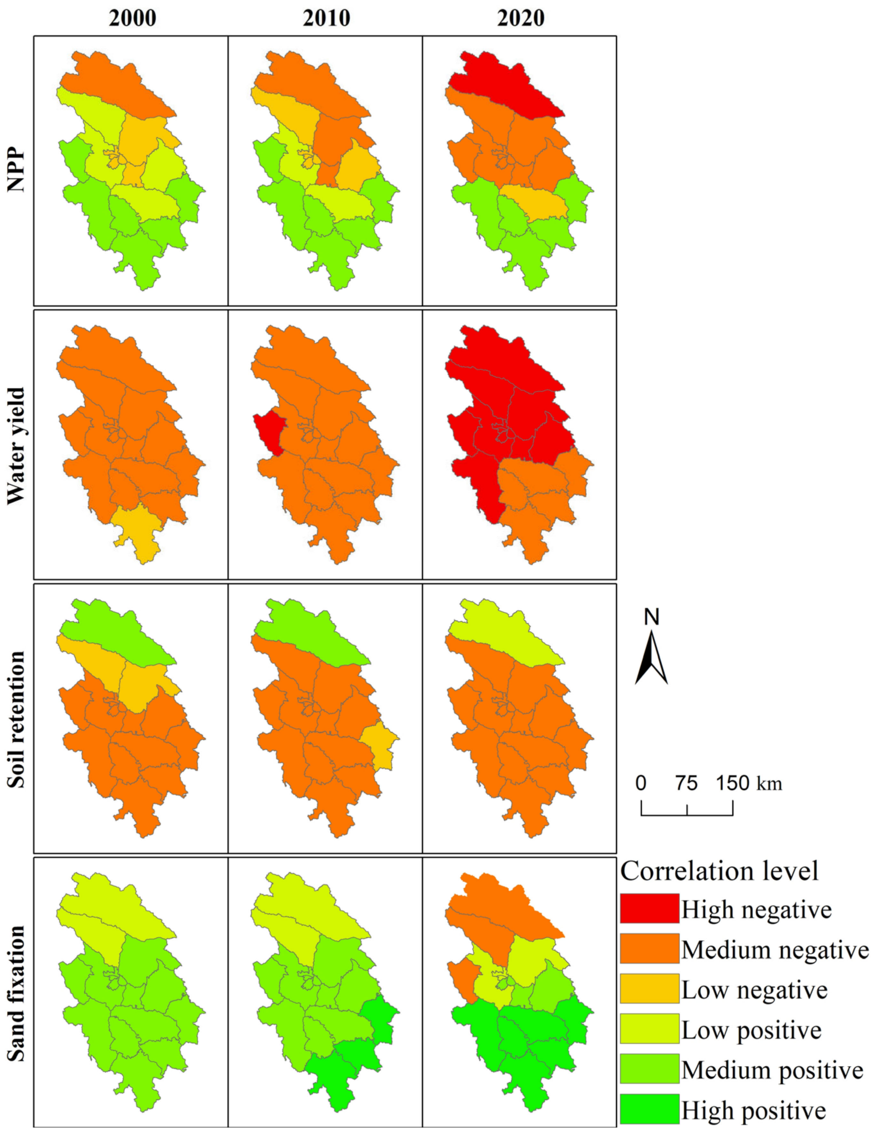

Figure 10. Spatiotemporal Distribution of Correlation Levels between ESs and SDL in the Counties of the Hehuang Valley from 2000 to 2020.

4. Discussion

4.1. Factors Influencing the Coupling Relationship between ESs and SDL

In this study, the coupling coordination model was employed to analyze the spatiotemporal changes in the coupling relationship between ESs and SDL in the Hehuang Valley from 2000 to 2020. The CCD between NPP, water yield, soil retention, and SDL generally increased. This can be attributed mainly to the continuous improvements in NPP, water yield, soil retention, sand fixation, and SDL throughout the study period. The heightened CCD between NPP and SDL can be primarily attributed to the implementation of various ecological protection policies and measures in the Hehuang Valley region. Since 2000, the Qinghai Forestry Bureau has issued pertinent policies and laws, including the Grain for Green Project, afforestation plans, and the Natural Forest Protection Project. As of 2020, Qinghai Province successfully completed 2886.7 km^2 of land greening, while forest pest control covered an area of 2139.7 km^2. These efforts have ensured the safety and healthy growth of forest and grassland resources. Furthermore, the forest and grassland resource protection system has been consistently enhanced, with 36,780 km^2 of natural forests and 39,771.1 km^2 of national public welfare forests being effectively managed.

From 2000 to 2014, Qinghai Province implemented various ecological restoration projects, including the conversion of farmland into forests and grasslands. As a result, the province increased its forest area by 6666.7 km^2, raising the forest coverage rate from 3.1% in 1999 to 6.1% in 2014. In addition, cultivation of steep slopes over 15 degrees was stopped in an area of 755.3 km^2, and soil erosion was effectively managed in an area of 7333.3 km^2, which successfully controlled soil erosion and improved soil retention. The increased precipitation in the upper reaches of the Yellow River and the source area of the Yangtze River led to an increase in river flow. Between 2003 and 2010, the average flow in the upper reaches of the Yellow River increased by 117.2 m^3/s, while the average flow in the Yangtze River source area increased by 149.4 m^3/s compared to the period of 1991–2002. The increase in precipitation, combined with the implementation of water pollution prevention regulations, contributed to a continuous rise in water yield. Moreover, the implementation of projects such as converting farmland to forests and grasslands significantly improved the structure of land use. With the introduction of mechanized operations and adjustments in crop structure, the grain yield per unit area steadily increased. Consequently, from 2005 to 2014, the total grain output in Qinghai Province increased from 932,600 tons to 1,023,700 tons, achieving steady growth and significantly enhancing income, thereby promoting local SDL. As a result, the CCD between water yield, soil retention, and SDL also steadily improved. The CCD between sand fixation and SDL underwent significant changes, transitioning from widespread imbalance in 2000 to basic coordination in some counties by 2020. This indicates an increase in the CCD. In 2020, Qinghai Province completed 1230 km^2 of sand control tasks, effectively protecting 5824 km^2 of desertified land and continuously improving the condition of desertified land in the Hehuang Valley.

4.2. Changes in the Spatiotemporal Relationship between ESs and SDL

The correlation between ESs and SDL is determined by the environmental quality and development direction of different regions [54,55]. A positive correlation implies that ecosystems contribute to SDL, while the capital investment generated by development can also enhance ecosystems. On the other hand, a negative correlation indicates that ecosystem degradation hampers SDL, which is often caused by human activities such as urbanization, industrialization, and farmland expansion [30].

From 2000 to 2020, there has been a gradual deterioration in the overall correlation between NPP, water yield, soil retention, and SDL, with a notable increase in negative correlation. Despite the implementation of policies aimed at protecting the ecological environment and promoting SDL during this period, urbanization has resulted in an expansion of construction land and transportation networks, disrupting the natural material cycles of the environment and causing damage to ecosystem functions [56]. Additionally, the predominant land use types in the region are grasslands and forests, which have slow growth rates, thus limiting the potential for improvement and hindering SDL in the area.

During the same period, the correlation between sand fixation and SDL exhibited contrasting trends in different regions. The northern region showed a negative correlation, while the southern region demonstrated a positive correlation. The northern region, which borders the Loess Plateau, is characterized by fragile ecosystems and has long been plagued by severe soil erosion [57]. Consequently, the northern region experiences severe wind erosion, which is detrimental to SDL. In contrast, the southeastern part of the valley benefits from moisture from the east [34], resulting in higher air humidity. The implementation of projects such as the conversion of farmland to forests and grasslands has increased vegetation coverage, yielding positive outcomes in terms of sand fixation in the southern region and fostering SDL.

4.3. Policies and Recommendations for Ecological Conservation

By comparing the relative development degrees of various ESs and SDL in 2020, the leading-lagging relationship between ESs and SDL for each county in the Hehuang Valley can be determined, as shown in Table 7. Based on the coupling coordination relationship and relative development types of ESs and SDL in each county, the counties are classified into the following five categories (Table 7): Comprehensive SDL Improvement Areas, NPP-Water Yield-Soil Retention SDL Improvement Areas, Water Yield Optimization Areas, Sand Fixation Optimization Areas, and Comprehensive Ecological Function Optimization Areas. Based on these classifications, specific policy recommendations are proposed.

Table 7. Relative Development Degree between ESs and SDL and Classification in the Hehuang Valley.

County	NPP-SDGs	Water Yield-SDGs	Soil Retention-SDGs	Sand Fixation-SDGs	Classification
Chengdong District	0.079	0.078	0.201	0.543	Comprehensive Ecological Function Lagging Type
Chengzhong District	0.610	0.224	0.108	0.221	Comprehensive Ecological Function Lagging Type
Chengxi District	0.183	0.046	0.048	0.724	Comprehensive Ecological Function Lagging Type
Chengbei District	0.297	0.067	0.238	1.884	Water Yield Lagging Type
Huangzhong County	2.947	1.229	0.956	0.580	Sand Fixation Lagging Type
Datong County	2.810	1.414	2.825	0.528	Sand Fixation Lagging Type
Huangyuan County	4.414	2.789	6.425	2.086	Comprehensive SDL Lagging Type
Ledu District	3.220	1.045	3.303	0.500	Sand Fixation Lagging Type
Ping'an District	3.229	1.323	0.584	0.416	Sand Fixation Lagging Type
Minhe County	2.802	0.881	2.088	0.700	Sand Fixation Lagging Type
Huzhu County	4.171	1.011	3.471	0.524	Sand Fixation Lagging Type
Hualong County	4.633	3.502	3.688	0.444	Sand Fixation Lagging Type
Xunhua County	6.966	5.586	1.753	0.547	Sand Fixation Lagging Type
Menyuan County	3.698	2.977	1.375	3.377	Comprehensive SDL Lagging Type
Tongren County	8.574	8.574	5.486	1.083	SDL Lagging in NPP-Water Yield-Soil Retention
Jianzha County	7.285	4.698	4.834	0.813	Sand Fixation Lagging Type
Guide County	3.169	4.532	2.481	1.058	SDL Lagging in NPP-Water Yield-Soil Retention

In the comprehensive SDL Improvement Areas (e.g., Huangyuan County, Menyuan County) and NPP-Water Yield-Soil Retention SDL Improvement Areas (e.g., Tongren County, Guide County), due to unique geography and environment, as well as limitations like weak infrastructure and significant poverty, the SDL in these counties are lower compared to urban areas. Emphasize county-level development to drive SDL through economic growth. Strengthen infrastructure construction, including transportation, communication, water, and electricity, to improve production and living conditions in surrounding areas. Leverage the economic influence of urban centers to transfer resources to nearby counties, achieving synchronized development and mutual benefits. Increase policy support, conduct poverty alleviation efforts, and provide basic guarantees for food, housing, and education for impoverished populations. Promote employment and improve educational conditions, as higher education levels are critical for sustainable development. Encourage industrial transformation and upgrading by introducing new technologies and cultivating new industries, optimizing and upgrading the industrial structure in surrounding areas, and aligning it with urban industries to enhance sustainable development capacity.

Water Yield Optimization Areas (e.g., Chengbei District) and Comprehensive Ecological Function Optimization Areas (e.g., Chengdong District, Chengzhong District, Chengxi District) both belong to the Urban areas, which are generally classified as ESs-lagging due to their relatively abundant resources and infrastructure, which accelerate sustainable development but also cause some environmental degradation. Protect and restore the local ecological environment by implementing strict ecological protection policies. Restore and reconstruct damaged ecosystems to enhance stability. Formulate stringent ecological protection policies to ensure that sustainable development aligns with environmental carrying capacity. Optimize industrial structure and layout to avoid overexploitation and disorderly expansion, ensuring coordination between ecosystems and sustainable development. Strengthen pollution regulation and management, ensure standard emissions, reduce environmental damage, and promote the development of low-energy, low-emission green industries to improve regional environmental quality.

Sand Fixation Optimization Areas (e.g., Huangzhong County, Datong County, Ledu District) should implement large-scale ecological projects such as afforestation to increase ground vegetation cover and enhance soil and water conservation and water source maintenance capabilities. Strengthen wetland protection to reduce the impact of sandstorms on the Hehuang Valley. Innovate in technology by developing sand fixation techniques suitable for the Hehuang Valley, improving sand control efficiency. Enforce policies for mountain closure for forest and grass cultivation, build soil and water conservation forests and artificial grasslands to reduce vegetation destruction on mountains. Strengthen soil erosion control to enhance soil retention capacity. Encourage enterprises to adopt green production methods to reduce pollution and resource waste, promoting the harmonious development of the economy and the ecological environment. Increase ecological education and awareness, improving public understanding of the importance of sand fixation and encouraging active public participation in ecological protection activities.

4.4. Limitations and Future Prospects

This study utilized three indicators—CCD, coupling degree, and relative development degree—to analyze the coupling relationship and leading-lagging dynamics between four types of ESs and SDL in the Hehuang Valley in 2020. The spatiotemporal GTWR model was also employed to explore the spatiotemporal heterogeneity between the two. However, there are some limitations to this study. The evaluation indicator system for SDL primarily focuses on social and economic indicators, with fewer ecological indicators. Additionally, the study used the entropy weight method to calculate the weights of the sustainable development indicators. Future research should consider expanding the dataset and incorporating expert opinions to determine weights in a way that combines both objective and subjective perspectives, enabling a more comprehensive and in-depth study. Despite these limitations, the research methods and results of this study provide valuable insights into the coupling relationship between ESs and SDL. The findings demonstrate that the ESs, SDL, and the CCD between the two in the Hehuang Valley are continuously improving, indicating the effective implementation of governance policies in the region. These findings serve as a reference for future ecological conservation and SDL in the Hehuang Valley. Moreover, the study's focus on the 17 counties of the Hehuang Valley as the study area and small administrative units as the research units contributes to the accuracy of the research. This approach allows for the formulation of solutions tailored to local characteristics, increasing their feasibility. Additionally, the study simultaneously analyzed the coupling relationship from both temporal and spatial perspectives, providing a comprehensive understanding of the intrinsic connections and interaction mechanisms between ESs and SDL. This provides strong support for the coordinated development of ESs and SDL.

5. Conclusions

The achievement of SDGs is not only about improving individual quality of life but is also closely linked to the health and development of the earth's entire ecosystem. By assessing the SDGs at the small administrative unit level and combining them with local geographical conditions and development status, it is possible to precisely identify and address existing issues, thereby facilitating substantial progress in sustainable development. In this context, this study explores the spatiotemporal heterogeneity and interactions between four ESs and SDL in the counties of the Hehuang Valley for the years 2000, 2010, and 2020, based on a constructed sustainable development assessment framework and utilizing the coupling model, relative development model, and GTWR model. The findings of the study are as follows:

(1) The SDL in the counties of the Hehuang Valley increased from 2000 to 2020, with Xining City exhibiting slightly higher levels compared to other counties. NPP and water yield increased from 2000 to 2010, but both decreased from 2010 to 2020. However, soil retention and sand fixation showed overall increases from 2000 to 2020. There was significant heterogeneity in the ability of the counties to provide ESs.

(2) The overall CCD between NPP, water yield, soil retention, sand fixation, and SDL increased from 2000 to 2020. The coordination between SDL and NPP was the highest, followed by soil retention and water yield, with sand fixation having the lowest coordination but the largest increase at 69.20%.

(3) From 2000 to 2020, most counties in the Hehuang Valley exhibited a relative development type where NPP, water yield, and soil retention lagged behind SDL. The relative development type for sand fixation and SDL varied significantly. From 2000 to 2010, sand fixation and SDL were mainly of the SDL-lagging type, whereas from 2010 to 2020, they were primarily of the sand fixation-lagging type.

(4) The negative correlation between the four ESs and SDL intensified from 2000 to 2020. In some counties, the positive contribution of NPP and sand fixation to SDL gradually turned negative, and the negative impact of water yield and soil retention on SDL continuously increased. The Impact of human activities on ecosystem function hindered local sustainable development.

Author Contributions: Conceptualization, Y.Y.; Formal analysis, Y.M.; Funding acquisition, H.W.; Methodology, K.W.; Visualization, M.L.; Writing—original draft, H.W. and K.W.; Writing—review & editing, Q.M. and Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Second Tibetan Plateau Scientific Expedition and Research Program (2019QZKK0608) and the Key Project of Henan Provincial Science and Technology R&D Plan Joint Fund (225200810045).

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Yackinous, W.S. *Understanding Complex Ecosystem Dynamics: A Systems and Engineering Perspective*; Academic Press: Cambridge, MA, USA, 2015.
2. Liu, J.; Mooney, H.; Hull, V.; Davis, S.J.; Gaskell, J.; Hertel, T.; Lubchenco, J.; Seto, K.C.; Gleick, P.; Kremen, C.; et al. Systems integration for global sustainability. *Science* **2015**, *347*, 1258832. [CrossRef] [PubMed]
3. Comberti, C.; Thornton, T.; de Echeverria, V.W.; Patterson, T. Ecosystem Services or Services to Ecosystems? Valuing Cultivation and Reciprocal Relationships between Humans and Ecosystems. *Glob. Environ. Chang.* **2015**, *34*, 247–262. [CrossRef]
4. Mononen, L.; Auvinen, A.P.; Ahokumpu, A.L.; Rönkä, M.; Aarras, N.; Tolvanen, H.; Kamppinen, K.; Viirret, E.; Kumpula, T.; Vihervaara, P. National ecosystem service indicators: Measures of social–ecological sustainability. *Ecol. Indic.* **2014**, *61*, 27–37. [CrossRef]
5. Dai, E.R.; Zhao, Z.X.; Jia, L.Z.; Jiang, X.T. Contribution of ecosystem services improvement on achieving Sustainable Development Goals under ecological engineering projects on the Qinghai–Tibet Plateau. *Ecol. Eng.* **2024**, *199*, 12. [CrossRef]

6. Dasgupta, R.; Hashimoto, S.; Gundimeda, H. Biodiversity/ecosystem services scenario exercises from the Asia–Pacific: Typology, archetypes and implications for sustainable development goals (SDGs). *Sustain. Sci.* **2019**, *14*, 241–257. [CrossRef]
7. Liu, Y.; Lü, Y.; Fu, B.; Zhang, X. Landscape pattern and ecosystem services are critical for protected areas' contributions to sustainable development goals at regional scale. *Sci. Total Environ.* **2023**, *881*, 163535. [CrossRef]
8. Liu, X.; Yuan, M. Assessing progress towards achieving the transport dimension of the SDGs in China. *Sci. Total Environ.* **2023**, *858*, 159752. [CrossRef]
9. Wu, X.; Liu, J.; Fu, B.; Wang, S.; Wei, Y.; Li, Y. Bundling regions for promoting Sustainable Development Goals. *Environ. Res. Lett.* **2022**, *17*, 044021. [CrossRef]
10. Liu, X.; Zhao, W.; Liu, Y.; Hua, T.; Hu, X.; Cherubini, F. Contributions of ecological programs to sustainable development goals in Linzhi, over the Tibetan Plateau: A mental map perspective. *Ecol. Eng.* **2020**, *176*, 106532. [CrossRef]
11. Griggs, D.; Nilsson, M.; Stevance, A.; McCollum, D. *A Guide to SDG Interactions: From Science to Implementation*; International Council for Science: Paris, France, 2017.
12. Xu, Z.; Peng, J.; Liu, Y.; Qiu, S.; Zhang, H.; Dong, J. Exploring the combined impact of ecosystem services and urbanization on SDGs realization. *Appl. Geogr.* **2023**, *153*, 102907. [CrossRef]
13. Smith, P.; Adams, J.; Beerling, D.J.; Beringer, T.; Calvin, K.V.; Fuss, S.; Griscom, B.; Hagemann, N.; Kammann, C.; Kraxner, F.; et al. Land-Management Options for Greenhouse Gas Removal and Their Impacts on Ecosystem Services and the Sustainable Development Goals. *Annu. Rev. Environ. Resour.* **2019**, *44*, 255–286. [CrossRef]
14. Mandle, L.; Shields-Estrada, A.; Chaplin-Kramer, R.; Mitchell, M.G.E.; Bremer, L.L.; Gourevitch, J.D.; Hawthorne, P.; Johnson, J.A.; Robinson, B.E.; Smith, J.R.; et al. Increasing decision relevance of ecosystem service science. *Nat. Sustain.* **2021**, *4*, 161–169. [CrossRef]
15. Costanza, R.; de Groot, R.; Braat, L.; Kubiszewski, I.; Fioramonti, L.; Sutton, P.; Farber, S.; Grasso, M. Twenty Years of Ecosystem Services: How Far Have We Come and How Far Do We Still Need to Go? *Ecosyst. Serv.* **2017**, *28*, 1–16. [CrossRef]
16. Zuo, L.; Liu, G.; Zhao, J.; Li, J.; Zheng, S.; Wang, J.; Su, X. Effects of ecosystem services on sustainable development goals in western Sichuan. *Acta Ecol. Sin.* **2024**, *44*, 4203–4216. (In Chinese)
17. Zhang, L.; Zhao, J.; Chen, G.; Lin, Y.; Liu, F.; Peng, S. Impact of Land-use Change on the Value of Ecosystem Services Based on SDG 15.3.1. *J. Soil Water Conserv.* **2024**, *38*, 268–277. (In Chinese)
18. Wood, S.L.R.; Jones, S.K.; Johnson, J.A.; Brauman, K.A.; Chaplin-Kramer, R.; Fremier, A.; Girvetz, E.; Gordon, L.J.; Kappel, C.V.; Mandle, L.; et al. Distilling the role of ecosystem services in the sustainable development goals. *Ecosyst. Serv.* **2018**, *29*, 70–82. [CrossRef]
19. Rozas-Vásquez, D.; Spyra, M.; Jorquera, F.; Molina, S.; Caló, N.C. Ecosystem Services Supply from Peri-Urban Landscapes and Their Contribution to the Sustainable Development Goals: A Global Perspective. *Land* **2022**, *11*, 2006. [CrossRef]
20. Hussain, K.; Sun, H.; Ramzan, M.; Mahmood, S.; Zubair Saeed, M. Interpretive Structural Modeling of Barriers to Sustainable Tourism Development: A Developing Economy Perspective. *Sustainability* **2024**, *16*, 5442. [CrossRef]
21. Yin, C.; Zhao, W.; Ye, J.; Muroki, M.; Pereira, P. Ecosystem carbon sequestration service supports the Sustainable Development Goals progress. *J. Environ. Manag.* **2023**, *330*, 117155. [CrossRef]
22. Yang, S.; Zhao, W.; Liu, Y.; Cherubini, F.; Fu, B.; Pereira, P. Prioritizing sustainable development goals and linking them to ecosystem services: A global expert's knowledge evaluation. *Geogr. Sustain.* **2020**, *1*, 321–330. [CrossRef]
23. Fang, X.; Shi, X.; Phillips, T.K.; Du, P.; Gao, W. The Coupling Coordinated Development of Urban Environment Towards Sustainable Urbanization: An Empirical Study of Shandong Peninsula, China. *Ecol. Indic.* **2021**, *129*, 107864. [CrossRef]
24. Wei, H.; Zheng, J.; Xue, D.; Dong, X.; Liu, M.; Zhang, Y. Identifying the Relationship between Livelihoods and Land Ecosystem Services Using a Coupled Model: A Case Study in the "One River and Two Tributaries" Region of Tibet. *Land* **2022**, *11*, 1377. [CrossRef]
25. He, L.; Du, X.; Zhao, J.; Chen, H. Exploring the coupling coordination relationship of water resources, socio-economy and eco-environment in China. *Sci. Total Environ.* **2024**, *918*, 170705. [CrossRef] [PubMed]
26. Yang, J.; Ma, X.; Zhao, X.; Li, W. Spatiotemporal of the Coupling Relationship between Ecosystem Services and Human Well-Being in Guanzhong Plain Urban Agglomeration. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12535. [CrossRef]
27. Yang, N. *Evaluation and Research on Sustainable Development of Land Ecology in Shanxi Province*; Harbin Institute of Technology: Harbin, China, 2020. (In Chinese)
28. Rezaee, Z.; Aliabadi, S.; Dorestani, A.; Rezaee, N.J. Application of Time Series Models in Business Research: Correlation, Association, Causation. *Sustainability* **2020**, *12*, 4833. [CrossRef]
29. Reyers, B.; Selig, E.R. Global targets that reveal the social–ecological interdependencies of sustainable development. *Nat. Ecol. Evol.* **2020**, *4*, 1011–1019. [CrossRef]
30. Yang, Z.; Zhan, J.Y.; Wang, C.; Twumasi-Ankrah, M.J. Coupling coordination analysis and spatiotemporal heterogeneity between sustainable development and ecosystem services in Shanxi Province, China. *Sci. Total Environ.* **2022**, *836*, 155625. [CrossRef]
31. Zhu, J.; Gong, J.; Li, J. Spatiotemporal change of habitat quality in ecologically sensitive areas of eastern Qinghai-Tibet Plateau: A case study of the Hehuang Valley, Qinghai Province. *Resour. Sci.* **2020**, *42*, 991–1003. [CrossRef]
32. Li, X.; Xin, Z.; Yang, J.; Liu, J. The spatiotemporal changes and influencing factors of vegetation NDVI in the Hehuang Valley of Qinghai Province from 2000 to 2020. *J. Soil Water Conserv.* **2023**, *13*, 79–90.
33. Vince, G. An epoch debate. *Science* **2011**, *334*, 32–37. [CrossRef]

34. Xue, D. Research on the Spatiotemporal Evolution of Land Use Functions and Its Coupling Relationship with Human Well-Being: A Case Study of Hehuang Valley. Master's Thesis, The Henan Agricultural University, Zhengzhou, China, 2023. (In Chinese)
35. Chen, R.; Zhou, Q.; Liu, F.; Zhang, Y.; Chen, Q.; Chen, Y. Contribution of climate change to food yield in Yellow River-Huangshui River Valley. *Hubei Agric. Sci.* **2018**, *57*, 114–119. (In Chinese)
36. Li, H.-H.; Huang, Y.-M.; Guo, W.; Hou, H.-Y.; Fan, M.-Y.; Qi, X.-P.; Jia, P.-H.; Guo, Q.-B. Influence of land use and land cover patterns on water quality at different spatio-temporal scales in Hehuang Valley. *Environ. Sci.* **2022**, *43*, 4042–4053. (In Chinese)
37. Hou, G.; Xu, C.; Li, X.; Qi, B. Spatial Pattern of Water Conservation Function in Hehuang Valley. *Ecol. Sci.* **2021**, *40*, 169–176. (In Chinese)
38. 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]
39. Zhu, W.Q.; Pan, Y.Z.; Zhang, J.S. Estimation of net primary productivity of Chinese terrestrial Vegetation based on remote sensing. *J. Plant Ecol.* **2007**, *31*, 413–424.
40. Sharp, R.; Douglass, J.; Wolny, S.; Arkema, K.; Bernhardt, J.; Bierbower, W.; Chaumont, N.; Denu, D.; Fisher, D.; Glowinski, K.; et al. *InVEST 3.10.2. User's Guide*; The Natural Capital Project, Stanford University: Stanford, CA, USA, 2020.
41. Chen, S.X.; Yang, X.H.; Xiao, L.L.; Cai, H.Y. Study of Soil Erosion in the Southern Hilly Area of China Based on RUSLE Model. *Resour. Sci.* **2014**, *36*, 10. (In Chinese)
42. Yi, K.; Wang, S.; Wang, X.; Yao, H. The Characteristics of Spatial–temporal Differentiation of Soil Erosion Based on RUSLE Model: A Case Study of Chaoyang City, Liaoning Province. *Sci. Geogr. Sin.* **2015**, *35*, 365–372.
43. Li, G.Z.; Zou, X.Y.; Cheng, H. Method of wind erosion sampling survey in China. *Sci. Soil Water Conserv.* **2013**, *11*, 17.
44. Qiu, J.Q.; Yu, D.Y.; Huang, T. Influential paths of ecosystem services on human well-being in the context of the sustainable development goals. *Sci. Total Environ.* **2022**, *852*, 158443. [CrossRef]
45. Ma, Y.; Ai, X. Evaluation of Sustainable Urbanization Development in Jilin Province Based on the 2030 Sustainable Development Goals. *Sci. Geogr. Sin.* **2019**, *39*, 487–495.
46. Kwatra, S.; Kumar, A.; Sharma, P. A Critical Review of Studies Related to Construction and Computation of Sustainable Development Indices. *Ecol. Indic.* **2020**, *112*, 106061. [CrossRef]
47. Meadows, D. Indicators and information systems for sustainable development. In *The Earthscan Reader in Sustainable Cities*, 1st ed.; Satterthwaite, D., Ed.; Routledge: London, UK, 1999; pp. 1–30.
48. Li, S.; Yu, D.; Li, X. Exploring the impacts of ecosystem services on human well-being in Qinghai Province under the framework of the sustainable development goals. *J. Environ. Manag.* **2023**, *345*, 118880. [CrossRef] [PubMed]
49. Wei, H.; Xue, D.; Huang, J.; Liu, M.; Li, L. Identification of Coupling Relationship between Ecosystem Services and Urbanization for Supporting Ecological Management: A Case Study on Areas along the Yellow River of Henan Province. *Remote Sens.* **2022**, *14*, 2277. [CrossRef]
50. Fotheringham, A.S.; Crespo, R.; Yao, J. Geographical and temporal weighted regression (GTWR). *Geogr. Anal.* **2015**, *47*, 431–452. [CrossRef]
51. Kim, J.H. Multicollinearity and misleading statistical results. *Korean J. Anesthesiol.* **2019**, *72*, 558–569. [CrossRef]
52. Kumar, S.; Lal, R.; Liu, D. A geographically weighted regression kriging approach for mapping soil organic carbon stock. *Geoderma* **2012**, *189*, 627–634. [CrossRef]
53. Kletting, P.; Glatting, G. Model selection for time-activity curves: The corrected akaike information criterion and the f-test. *Z. Med. Phys.* **2009**, *19*, 200–206. [CrossRef]
54. An, Q.; Yuan, X.; Zhang, X.; Yang, Y.; Chen, J.; An, J. Spatio-Temporal Interaction and Constraint Effects between Ecosystem Services and Human Activity Intensity in Shaanxi Province, China. *Ecol. Indic.* **2024**, *160*, 111937. [CrossRef]
55. Li, W.; Wang, Y.; Xie, S.; Cheng, X. Coupling coordination analysis and spatiotemporal heterogeneity between urbanization and ecosystem health in Chongqing municipality, China. *Sci. Total Environ.* **2021**, *791*, 148311. [CrossRef]
56. Mo, W.; Wang, Y.; Zhang, Y.; Zhuang, D. Impacts of road network expansion on landscape ecological risk in a megacity, China: A case study of Beijing. *Sci. Total Environ.* **2017**, *574*, 1000–1011. [CrossRef]
57. Sun, W.; Song, X.; Mu, X.; Gao, P.; Wang, F.; Zhao, G. Spatiotemporal vegetation cover variations associated with climate change and ecological restoration in the Loess Plateau. *Agric. For. Meteorol.* **2015**, *209*, 87–99. [CrossRef]