remote sensing

MDPI

Article

Shifting from Trade-Offs to Synergies in Ecosystem Services Through Effective Ecosystem Management in Arid Areas

Yan Xu [1,2,†], Xiaoyun Song [3,†], Mingjiang Deng [1,2,*], Tao Bai [1] and Wanghai Tao [1]

[1] State Key Laboratory of Eco-Hydraulics in Northwest Arid Region of China, Xi'an University of Technology, Xi'an 710048, China; xjsltxy@163.com (Y.X.); baitao@xaut.edu.cn (T.B.); xautsoilwater@163.com (W.T.)
[2] Engineering Research Center of Water Resources and Ecological Water Conservancy in Cold and Arid Area of Xinjiang (Academician Workstation), Urumqi 830052, China
[3] State Key Laboratory of Hydraulic Engineering Intelligent Construction and Operation, Tianjin University, Tianjin 300350, China; songxiaoyun@tju.edu.cn
* Correspondence: xjdmj@163.com
† These authors contributed equally to this work.

Abstract: Human activities continuously alter the delivery of ecosystem services (ESs), which play a crucial role in human well-being. There is a pressing need for effective ecological management strategies that consider the spatial heterogeneity of ESs to support the transition from trade-offs to synergies. This study focuses on the Haba River Basin and examines characteristics of land-use change and the shift from trade-offs to synergies. The results indicate that from 1990 to 2000, the initial phase of land development, 10.65% of the land experienced change. Subsequently, during the intensive period of land development from 2000 to 2010, 30.29% of the land underwent significant transformation, with approximately 78% of grassland, sparse grassland, forested land, and desert converted into arable land. However, between 2010 and 2020, as the focus shifted towards the establishment of native vegetation. The intensity of land development decreased, and only a small percentage (3.65%) of the total area underwent changes. Based on an in-depth analysis of spatial heterogeneity from 1990 to 2020, it is believed there has been a shift from trade-offs to co-benefits between 2000–2010 and 2010–2020. The years 2010 and 2020 were pivotal time nodes for the transition from trade-offs to synergies and for reducing trade-offs, with NPP identified as a critical driving factor for comprehensive ES (CES) functions. By considering the trade-off–synergy relationship and hotspots of ecological service functions, combined with unified water resource management policies, comprehensive ecological management measures tailored to different regions are proposed. These measures have facilitated the implementation of robust ecological protection policies to shift ES development from trade-offs to synergies in arid areas, thereby enhancing overall ecosystem service functions in the Haba River Basin. The research findings offer crucial scientific support and guidance for ecosystem management in arid areas, particularly within Central Asia.

Keywords: ecosystem services; spatiotemporal pattern; arid area; trade-offs and synergies; Central Asia

check for updates

Citation: Xu, Y.; Song, X.; Deng, M.; Bai, T.; Tao, W. Shifting from Trade-Offs to Synergies in Ecosystem Services Through Effective Ecosystem Management in Arid Areas. *Remote Sens.* **2024**, *16*, 4115. https://doi.org/10.3390/rs16214115

Academic Editor: Jeroen Meersmans

Received: 12 September 2024
Revised: 28 October 2024
Accepted: 29 October 2024
Published: 4 November 2024

Copyright: © 2024 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Ecosystem services (ESs) were defined in the Millennium Ecosystem Assessment (MA) by the United Nations as the benefits gained by humans from ecosystems [1]. The stock of natural capital is crucial for Earth's life-support system and connects natural ecosystems and human well-being [2,3]. Due to the ongoing development of global socio-economics, factors such as population growth, expansion of cultivated land, and increasing urbanization have resulted in a significant decline in ESs, posing a threat to human survival and health [4,5].

Generally, there are three types of relationship between ESs: synergistic, trade-offs, and neutral. A trade-off occurs when one service negatively affects another. When two

services positively change in the same direction, they are termed synergistic [6]. The human development and exploitation of resources, without considering the trade-offs or synergies between ESs, may diminish certain ecosystems' capacity and threaten their security. Land use indicates the interplay between socio-economic and natural systems, directly influencing ESs [7]. Analyzing the changes in the relationship between land use and ES function helps when proposing better strategies for ecosystem restoration [8]. In recent years, the relationship changes between ESs have become a research focus. Scholars have quantitatively evaluated relationships between different ESs using various methods [9,10]. Numerous studies have delved into the trade-offs and synergies within the four categories of ecosystem service, as well as their respective subtypes, such as freshwater and food supply [11]. Research into trade-offs in ESs has become essential for strategic planning, effective management, and informed decision-making [12]. Consequently, assessing ESs and studying trade-offs or synergies can significantly guide ecological management and enhance human well-being [13].

Currently, global ecosystems are confronted by a multitude of challenges, particularly in arid regions. These include the expansion of cultivated areas, the retreat of wetlands, deforestation, overgrazing, intensified desertification, conflicts over water resources due to excessive development, reduced capacity for vegetation carbon sequestration and soil retention, and diminished biological conservation capacity. These challenges have presented significant obstacles to ESs, especially in regulating services [14–18]. Hence, research into ESs has expanded to include the evaluation of spatiotemporal dynamics and associated trade-offs/synergies across various spatial and temporal scales [19]. In terms of spatial scale, this encompasses analysis at the national level [20], regional level [12], river basin level [21], provincial level [22], and urban level [23]. Numerous scholars are currently directing their attention toward various areas at differing spatial scales, such as the Altay region, the economic belt of the northern slope of the Tianshan Mountains, and the Shiyang River Basin, to research ecosystem service functions within arid regions. These studies suggest that the spatial distribution of trade-offs and synergies that change with changing land use can affect the provision of ESs [21].

While much of the existing research has made significant progress in examining ecosystem service trade-offs at larger spatial scales [24], relatively less attention has been given to smaller spatial scales, particularly in arid regions. Ecosystem trade-offs at these finer scales are often underexplored in ecological management practices. Although some studies have begun to investigate the spatial heterogeneity and trade-offs/synergies of key ecosystem services such as carbon storage, water conservation, soil retention, and net primary productivity at the county level, the number of such studies remains limited [25]. However, researchers have failed to effectively consider spatial heterogeneity in accurately delineating the trade-off/synergy dynamics across various regions within the study area [20]. This is why contemporary ecological management predominantly relies on macro-level strategies (e.g., overgrazing, deforestation), posing challenges for implementing targeted management interventions [26].

It is imperative to characterize the finer spatial heterogeneity of ESs in arid areas, elucidate the mechanisms of effective ecosystem management in balancing and coordinating changes in ESs, propose efficient ecological management strategies for diverse regions, facilitate the transition of ESs from equilibrium to coordination, and enhance the functionality of ESs. These are critical scientific inquiries that warrant further exploration. To address this critical need, the present study involved a spatial analysis of land-use changes spanning the period from 1990 to 2020 and investigated the spatiotemporal variations of four essential ecosystem functions: water conservation (WC), soil retention (SC), biodiversity conservation (BC), and oxygen release and carbon sequestration (CS). Ultimately, the study comprehensively compared the spatial balance/coordinated relationships of ecosystem functions with the overall functional changes in hot- and cold-spot areas over the last three decades. The primary objectives of this study were to elucidate the mechanism of transition from trade-off to synergies in arid areas, propose ecological governance measures

tailored to different regions, facilitate the shift of ESs from trade-offs to synergies, refine and enhance the overall functions of ESs in the entire region, and provide guidance for effective ecological management in arid areas. The findings of this study can offer scientific insights for the effective management of similar regions in the world's arid areas, mainly providing crucial technological support for managing ecosystems in ecologically vulnerable regions such as the Aral Sea Basin and Tarim River Basin in Central Asia [27], as well as arid areas in Africa [28].

This study aimed to characterize the spatial heterogeneity of ES, promote transitions from trade-offs to synergies between ES, propose effective management measures for different partitions within the whole basin, and serve as a crucial scientific reference for effective management in arid areas (Figure 1).

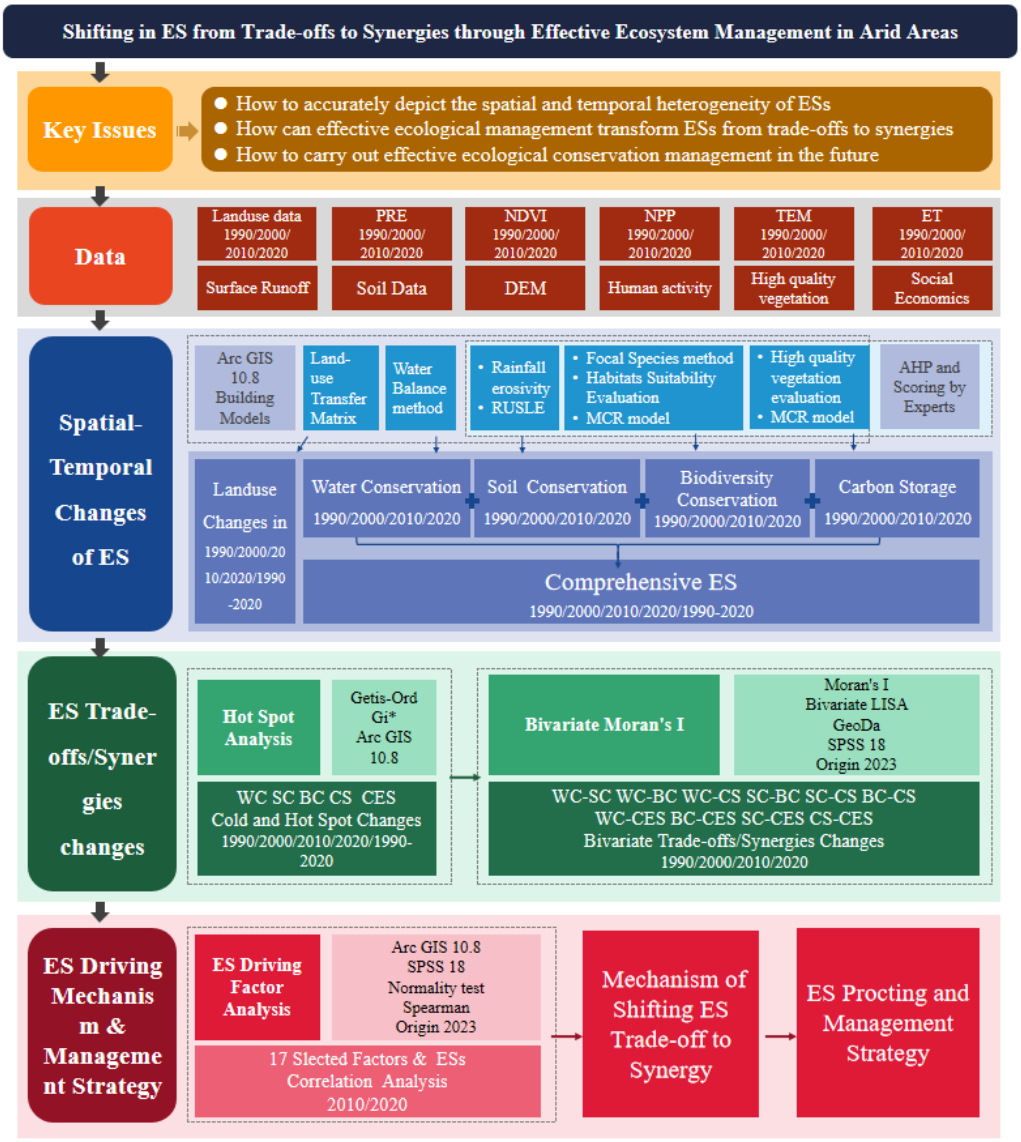


Figure 1. The overall framework of the study.

2. Materials and Methods

2.1. Study Area

The Haba River Basin, situated in Altay Prefecture of the Xinjiang Uygur Autonomous Region in northwest China, is located between 85°31′–87°09′E and 47°38′–49°09′N, covering an area of 8180.57 km^2. Positioned within the heartland of the Eurasian continent, it forms a crucial part of the Irtysh River Basin. It is considered one of the key ecological

functional zones in northwest China [29] (Figure 2). This region experiences a typical continental cold climate with low precipitation and high evaporation rates. With annual precipitation of just 205.6 mm and an average yearly temperature of 5.3 °C, it holds significant ecological importance within Central Asia's arid expanse [30]. The area is home to rare wildlife species such as elk, cranes, and argali sheep, along with diverse varieties of poplar trees, including silver poplar. It is the only natural habitat for poplar forests in China and serves as a genetic repository for various poplar species, showcasing a distinctive oasis desert landscape [31,32]. The uneven distribution of water resources has led to water scarcity becoming a primary constraint on socio-economic development and ecological balance within the region. At the same time, it represents an important agricultural and pastoral development zone within arid regions.

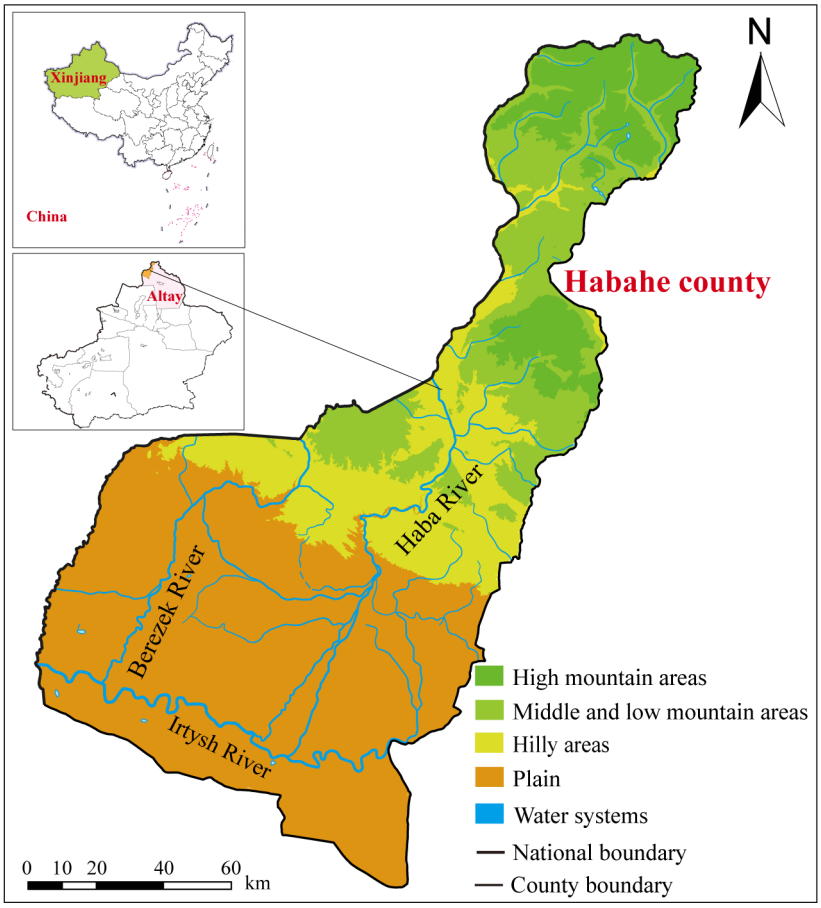


Figure 2. Overview of the study area.

However, intensive human activities have resulted in significant ecological challenges, including the development of agricultural water and soil resources and extensive use of irrigation systems, which have led to rising groundwater levels downstream and secondary salinization issues. Overgrazing and drought have also contributed to grassland degradation, desertification, and a decline in biodiversity. In response to these challenges, China has implemented various management policies and projects such as ecological water replenishment, returning farmland to forest or grassland, grazing prohibition, and grassland protection subsidies. These efforts have effectively addressed critical socio-economic development and ecological restoration challenges [33], resulting in improvements in the ecosystem services (ESs) within the Haba River Basin.

Therefore, this study focuses on the Haba River Basin not only because of the severe ecosystem degradation caused by human interference but also because it is a typical area

for promoting effective ecological restoration through management practices. This makes it a valuable experimental area for conducting this study.

2.2. Data Resources

Table 1 shows the primary data sources. For the study, land-use raster data for 1990, 2000, 2010, and 2020 were obtained from the Resources and Environmental Sciences, Chinese Academy of Sciences (RESDC) (https://www.resdc.cn/, accessed on 6 April 2023) with a spatial resolution of 30 m. The land-use types for the four periods were reclassified using ArcGIS 10.8 software, categorizing them into nine types: farmland, forest, shrubland, grassland, sparse grassland, water, wetlands, desert, and construction land. Land-use classification results were further corrected on the basis of field surveys with interpretation accuracy reaching more than 90%. A digital elevation model (DEM) was downloaded from the Geospatial Data Cloud platform (https://www.gscloud.cn, accessed on 20 April 2023) with a spatial resolution of 30 m. Slope and aspect were computed based on the DEM. Meteorological station data from around the Haba River Basin for 1961–2020 were extracted from the China Meteorological Science Data Center (http://data.cma.cn/, accessed on 12 April 2023), providing multi-year precipitation data. The precipitation data for 1990, 2000, 2010, and 2020 were derived from 1 km raster data using Kriging interpolation. Soil texture and type spatial data were sourced from a 1:1,000,000 soil database (https://www.resdc.cn, accessed on 14 April 2023) with a 1 km resolution. Monthly evapotranspiration data and NPP datasets were sourced from the National Ecosystem Science Data Center Data Platform (http://www.nesdc.org.cn/, accessed on 21 April 2023). In contrast, the NDVI dataset was obtained from the geographic remote sensing ecological network platform (http://www.gisrs.cn/, accessed on 22 April 2023) with a spatial resolution of 1 km. Socio-economic data were sourced from the Haba River County Chronicles and the Haba River Yearbook.

Table 1. Data used in the study.

Name	Spatial Resolution	Reference Year	Used for	Data Preprocessing	Data Sources
DEM	30 m	-	SC/BC/CS	Extracting slope and aspect data through Arc GIS 10.8	Geospatial Data Cloud (https://www.gscloud.cn, accessed on 20 April 2023)
LUCC	30 m	1990/2000/2010/2020	WC/BC/CS	According to field investigations, the land-use types were reclassified into nine first-level types by Arc GIS 10.8	Resources and Environmental Sciences, Chinese Academy of Sci-ences (RESDC) (https://www.resdc.cn, accessed on 6 April 2023)
PRE	1 km	1961–2020	WC/SC/CS	The data from surrounding meteorological stations were extracted, and the precipitation data were interpolated by kriging in Arc GIS 10.8	National Meteorological Science Data Center (http://data.cma.cn, accessed on 12 April 2023
NDVI	1 km	1990/2000/2010/2020	SC	Normalization by Arc GIS10.8 fuzzy membership degree	Geographic remote sensing ecological network platform (http://www.gisrs.cn/, accessed on 22 April 2023)
NPP	1 km	1990/2000/2010/2020	CS	Normalization by Arc GIS10.8 fuzzy membership degree	National Ecosystem Science Data Center (http://www.nesdc.org.cn, accessed on 21 April 2023)
TEM	1 km	1990/2000/2010/2020	CS	Annual average temperature data	National Meteorological Science Data Center (http://data.cma.cn, accessed on 12 April 2023)

Table 1. *Cont.*

Name	Spatial Resolution	Reference Year	Used for	Data Preprocessing	Data Sources
ET	1 km	1990/2000/2010/2020	WC/CS	Monthly data rasters were overlaid and calculated as annual evapotranspiration data	National Ecosystem Science Data Center (http://www.nesdc.org.cn/, accessed on 21 April 2023)
Soil data	1 km	-	SC	Spatial distribution data of soil texture and soil type were reclassified	Resources and Environmental Sciences, Chinese Academy of Sci-ences (RESDC) (https://www.resdc.cn, accessed on 6 April 2023)
Socio-Economic data		1950–2020	Driving factors	Perform spatial statistics and make spatial grids	Field investigation, Habahe County Records, Habahe Yearbook

Note: WC is water conservation, SC is soil conservation, BC is biodiversity conservation, CS is carbon storage, and CES is comprehensive ES.

To ensure consistent calculation, all data were first geographically corrected through coordinate projection, ensuring they were in the same coordinate system before being cropped according to the study area. Subsequently, the resampling tool in ArcGIS was used to unify the data required for evaluating the four ESs to a spatial resolution of 250 m × 250 m.

2.3. Methods

First, spatial changes in the study area were analyzed using a land-use transfer matrix. Based on methods such as water balance equations, soil erosion equations, habitat suitability assessment, the NPP quantitative index method, and the minimum cumulative resistance model, the spatiotemporal heterogeneity of four typical ES functions (WC, SC, BC, and CS) within the study area were characterized. By integrating these four ES categories, the temporal and spatial evolution characteristics of the comprehensive ES (CES) over the past 30 years were obtained. Second, temporal and spatial variations in the four individual ES and CES were analyzed utilizing spatial hotspot analysis methods. By deriving both bivariate global and local Moran's I indices, the spatial tradeoffs/synergies between various ESs were explored at the whole basin and grid scales, quantifying the contributions of the four individual ESs to the CES.

Furthermore, by comparing and analyzing the years 1990, 2000, 2010, and 2020, under intense human activity interference, years with the most effective ecological service functions and those with significantly declining ecosystem service functions were identified. An assessment was made to determine whether ES functions have improved in recent years, identifying relationships transitioning from trade-offs to synergies among the ESs or revealing declining trade-off patterns. Third, seventeen representative natural, social, and economic factors were selected [34]. Through Spearman correlation analysis, the quantitative impacts of these 17 factors on various ESs over nearly a decade were assessed, uncovering the driving mechanisms behind ES changes.

2.3.1. ES Evaluation Methods

Based on the Millennium Assessment, the study selected four key ES indicators and quantified them from 1990 to 2020. These indicators were water conservation (WC), soil conservation (SC), biodiversity conservation (BC), and carbon storage (CS) [35]. The detailed evaluation processes for each ES are shown in Table 2. WC represents the critical regulating service that ecosystems provide [36]. In the study, the water conservation function of the area was assessed by calculating the water balance equation using ArcGIS 10.8. SC is an essential safeguard against regional land degradation and flood risk prevention [37]. Using the modified RUSLE model, we performed raster calculations in ArcGIS 10.8 based on single-factor evaluation data reflecting the sensitivity of various factors to soil erosion. Within the BC function, habitats are crucial areas that promote ecological

processes and sustain ES functions, ensuring regional biodiversity and sustainable development [38]. Compared to previous studies that often used a single habitat suitability assessment method in models to determine habitat quality, this study evaluated habitat suitability for several focal species in the arid areas based on actual species diversity surveys. This approach reflects the critical role of ESs in biodiversity conservation. CS is a vital ecosystem service [39], and vegetation growth is a crucial metric for carbon sequestration and oxygen release. The study employed the NPP quantitative index method to evaluate vegetation ecosystems [40], in combination with the MCR model to simulate the diffusion process of vegetative genetic resources and study the distribution of regional carbon storage capabilities. CES was constructed by integrating multiple key ES functions, considering the overall spatial heterogeneity in the study area [41]. The evaluation process for each function is detailed in Table 2, and relevant model evaluation indicators can be found in Supplementary S1 [42–57].

Table 2. ES Evaluation Methods.

ESs	Methods	Evaluation Steps
WC	Water balance method [58]	The water balance equation: $TQ = \sum_{i=1}^{j} (P_i - R_i - ET_i) \times A_i \times 10^3$ (1) where TQ is the total water conservation capacity (m), P_i represents the annual average precipitation (mm), R_i represents the annual average surface runoff (mm), ET_i represents the annual evapotranspiration (mm), A_i represents the area of the nth type of ecosystem in the study area (km^2), i represents the type of ecosystem in the study area, and j represents the number of ecosystem types in the study area.
SC	Soil conservation capacity evaluation [59]	Rainfall erosivity calculation: $R_i = \sum_{i=1}^{12} \left[1.735 \times 10^{(1.5 \times lg \frac{P_i}{P} - 0.8188)}\right]$ (2) Soil conservation capacity(RUSLE) $SS_i = \sqrt[4]{R_i \times K_i \times LS_i \times C_i}$ (3) where SS_i is the sensitivity index to soil erosion, R_i represents rainfall erosivity, P_i represents monthly rainfall (mm), K_i represents soil texture factor, LS_i represents terrain undulation (m), and C_i represents vegetation cover. Sorting and classifying soils of different textures based on their erosion resistance capabilities.
BC	Habitat suitability evaluation [45]	Focal species method According to the criteria of the focal species method [46,47], the common crane (*Grus grus*), Przewalski's gazelle (*Procapra przewalskii*), and red deer (*Cervus*) were selected as representative focal species for typical ecosystem types in arid regions. Habitat suitability evaluation Clearly define the specific factors and weights of habitat preferences for each focal species [50], conduct suitability evaluations, and identify the "ecological source areas" for species (evaluation criteria can be found in Supplementary S1). MCR model Based on the spatial movement patterns of the selected focal species, by simulating their process of overcoming resistance to movement within the landscape, establish a resistance surface, and identify the species migration process using the minimum cumulative resistance (MCR) model: $MCR = f\min \sum_{j=n}^{i=m} (D_{ij} \times R_i)$ (4) where MCR is the minimum cumulative resistance value required to travel from the source to the destination, reflecting the accessibility from the "source" landscape to the destination. A larger value indicates that the resistance the "source" landscape exerts, which needs to be overcome to reach the destination, is greater, making it more challenging to reach.

Table 2. *Cont.*

ESs	Methods	Evaluation Steps
CS	NPP quantitative index method [60]	NPP quantitative index method: $S_{bio} = NPP_{\text{mean}} \times F_{\text{pre}} \times F_{\text{tem}} \times (1 - F_{\text{alt}})$ (5) where S_{bio} is the biodiversity maintenance service capacity index, NPP_{mean} represents the average net primary productivity of vegetation over multiple years, F_{pre} represents the average annual rainfall over multiple years, F_{tem} represents the average annual temperature over multiple years, and F_{alt} represents the altitude factor High-quality vegetation evaluation Based on the vegetation ecosystem evaluation results, select high-quality vegetation (forests, grasslands, wetlands) as the "source" for the dispersion of plant genetic resources and assign different resistance values to them. MCR model Simulate the dispersion process of plant genetic resources using the MCR model: $MCR = f\min\sum_{j=n}^{i=m}(D_{ij} \times R_i)$ (6)
CES	Cumulative equation [61]	CES calculation After normalizing each ES, the ESs are reclassified into four levels: excellent, good, average, and poor. Then, the CES is calculated using the raster calculator in ArcGIS 10.8: $CES = (ES_1 + ES_2 + ... + ES_n)/n$ (7) where CES is the comprehensive ecosystem service function, ES_1 refers to the first type of ES function, and n represents a total of n types of ES functions.

Note: WC is water conservation, SC is soil conservation, BC is biodiversity conservation, CS is carbon storage, and CES is the comprehensive ES.

2.3.2. ES Trade-Offs and Synergies

- Hotspot Analysis Method

Hotspot analysis can identify regions exhibiting significant changes in ecosystem service functions, and the Getis-Ord G_i^* statistic is employed to examine the spatial clustering and distribution of ESs [62]. Hotspot areas consist of three levels: extremely significant hotspots (99% confidence), significant hotspots (95% confidence), and less significant hotspots (90% confidence). Cold-spot areas also include extremely significant cold spots (99% confidence), significant cold spots (95% confidence), and less significant cold spots (90% confidence), with the rest being non-significant areas.

- Bivariate spatial correlation analysis

The study used Moran's *I* (including bivariate global Moran's *I* and local Moran's *I*) to explore the spatial tradeoffs and synergies between different types of ES and between ES and CES. Using the GeoDa 1.20.0.36 software, the global Moran's *I* was employed to determine if there is a spatial correlation between various types of ESs across the entire region and to what extent this spatial correlation exists. Meanwhile, the local bivariate Moran's *I* indicates the spatial correlation of different ESs within distinct spatial grids [63].

Next, the local bivariate spatial correlation is visualized using the bivariate LISA method. The generated local spatial correlation types consist of four categories: H-H, H-L, L-H, and L-L. H-H represents a high-value cluster of the bivariate, H-L indicates high values clustered around low values, L-H denotes low values clustered around high values, and L-L signifies a low-value cluster of the bivariate. The study comprehensively considered various natural, economic, and social factors influencing ESs and identified 17 factors for driving force analysis (Table 3 and Supplementary S2) [64–67].

Table 3. ES driving factors.

Factor Type		Factors	Symbol	Description
Natural factors		PRE	X_1	Precipitation
		TEM	X_2	Temperature
		ET	X_3	Evaporation
		NPP	X_4	Net primary productivity
		NDVI	X_5	
		DEM	X_6	
		Slope	X_7	
		Surface runoff	X8	
		Soil erosion	X9	
		Soil type	X_{10}	
Social and economic driving factors	Land use intensity	Comprehensive index of land use degree	X_{11}	$\mathbf{M} = \sum_{i=1}^{n} \mathbf{A_i} \times \frac{C_i}{C} \times 100\%$ M represents the comprehensive index of land-use degree in study area, $\mathbf{A_i}$ is the grade i land-use degree classification number, Ci and C are the grade i land-use area and the total area of land within the region, respectively, n is the grade of land-use degree classification (unused land = 1, woodland, grassland and water area = 2, cultivated land = 3, construction land = 4) (Van, 2015).
		Population density	X_{12}	(people/100 hectares)
		Per cultivated area	X_{13}	(people/hectare)
		Livestock density	X_{14}	(head/100 hectares)
	Regional economy	GDP	X_{15}	(RMB 10,000)
Comprehensive ecosystem service	Location factor	Distance to road	X_{16}	m
		Distance to river	X_{17}	m
	Water conservation		WC	
	Soil conservation		SC	
	Biodiversity conservation		BC	
	Carbon storage		CS	
	Comprehensive ecosystem service		CES	

3. Results

3.1. Land-Use Change and Transition

Grassland, sparse grassland, desert, forested land, and farmland are the main land types in the Haba River basin. Of these, grassland (39.6%) and sparse grassland (27.5%) are the most widespread and cover the largest land types. From 1990 to 2010, the largest increases were in grassland (23,309.7 hectares), arable land (16,275.6 hectares), and desert (12,379.8 hectares). The most considerable area reduction was 30,809.9 hectares of forest land and 13704.8 hectares of shrub land. The wetland area increased significantly, and the construction land and water body areas did not fluctuate much. Over the thirty years, the most converted land types were grassland, forest, sparse grassland, and desert. Comparing 1990–2000, 2000–2010, and 2010–2020, the land-use changes were relatively small in the first and last decades. However, the middle decade witnessed more significant fluctuations. In the first decade, there was a notable transformation from forest to grassland in mountain areas.

In contrast, during the middle decade, changes were most evident on the oasis plains. In recent years, the primary land-use change has been an expansion of farmland and a reduction in wasteland, but the rate of farmland expansion has shown a declining trend (Supplementary S3). This indicates that ecological protection and restoration reservoir ecological regulation have effectively controlled the continuous expansion of farmland and grassland degradation. From 1990 to 2000, 10.7% of the land experienced transitional changes. From 2000 to 2010, this figure rose to 30.3%, with the majority of the increased

farmland originating from grassland (accounting for 44.2%), sparse grassland (accounting for 26.6%), forest (accounting for 50.3%), and desert. From 2010 to 2020, only 3.7% of the land underwent transition, with the majority of new farmland coming from sparse grassland at 78.9%. The increased grassland mainly originated from forest (accounting for 47.6%), sparse grassland, and desert (Figure 3).

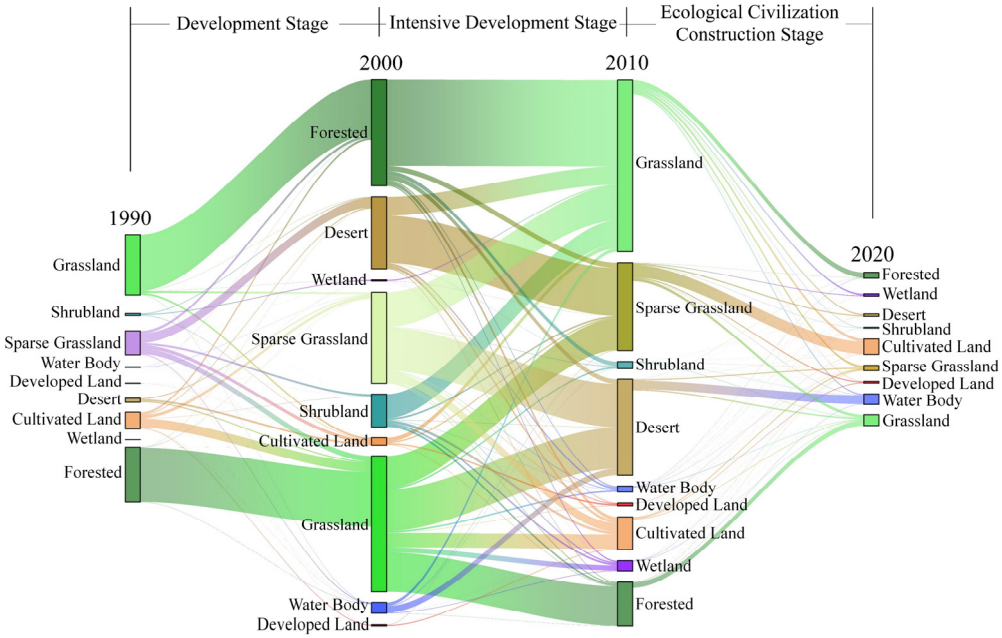


Figure 3. Land-use area transition from 1990 to 2020.

3.2. Spatiotemporal Heterogeneity of ES

Spatiotemporal distribution characteristics of WC, SC, BC, and CS are detailed in Supplementary S4. Area percentages of four ES significance levels are shown in Figure 4. Based on the spatiotemporal distribution characteristics of WC, it was found that regions with high WC functionality are mainly concentrated in the northern high mountain areas. Over the past 30 years, the area of regions with poor functionality has been increasing, indicating a gradual degradation in WC functionality. Examining the spatiotemporal distribution of SC, a decline in SC functionality was observed; in particular a significant reduction in the area with excellent functionality. Over the last three decades, SC functionality has exhibited a significant downward trend, especially in the plains areas.

Regarding the spatiotemporal distribution of BC, areas with excellent functionality remained relatively stable, mainly distributed in the northern high mountains, middle and low mountains, hilly areas, and along the southern riverbanks on the plains. However, on the plains, the functionality was originally rated as excellent, but it transformed into areas rated average and poor around 2000, indicating severe habitat degradation. Although there was some recovery after 2010, the habitat remained fragmented. With the construction of ecological channels and supplementary ecological water, BC in the plains has improved. Examining the spatiotemporal distribution of CS, fluctuations were observed from 1990 to 2020. The area with excellent functionality experienced a sharp decline around 2010, but showed recovery by 2020. The area with poor functionality peaked in extent in 2010 and then declined, indicating some functional recovery. Geographically, significant degradation in ecological functions occurred along riverbanks on the plains around 2010, but showed a noticeable recovery by 2020.

Analyzing the spatiotemporal changes in CES (Figure 5) from 1990 to 2020, functionality has improved overall in the northern high mountain areas and middle and low mountain areas, although localized ecological degradation exists. The CES has seen positive development, with 2010 showing the most significant decline. The plains have experienced

the most pronounced and concentrated changes in ecological functionality, with varying degrees of ecological degradation along riverbanks. The most severe degradation occurred in 2010, but by 2020, ecological functionality was significantly improved along riverbanks. Our data indicate that a series of ecological management policies have been implemented to improve the water condition of the ecosystem in the Haba River Basin.

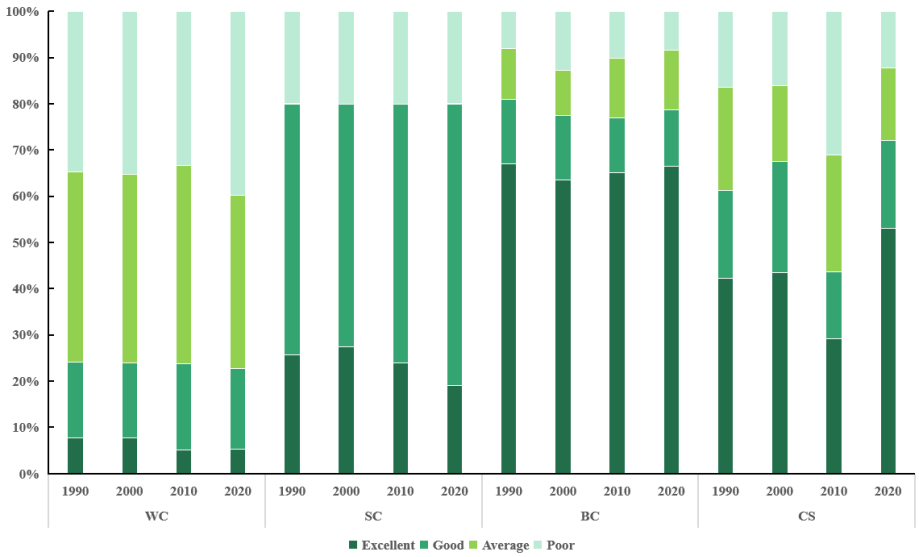


Figure 4. Area percentage of four ES significance levels. WC is water conservation, SC is soil conservation, BC is biodiversity conservation, and CS is carbon storage.

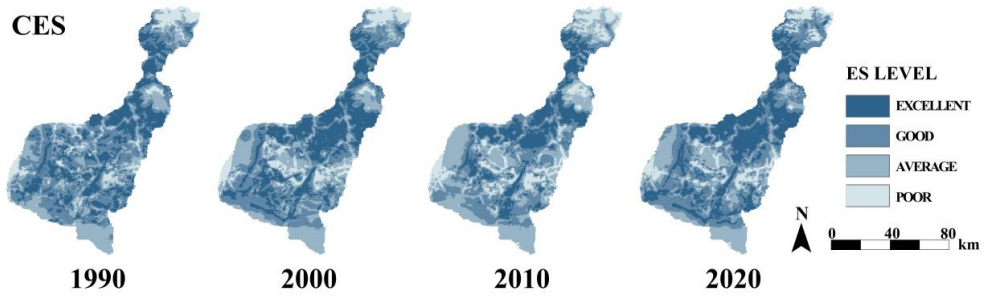


Figure 5. Spatial and temporal changes in comprehensive ES from 1990 to 2020.

3.3. Changes in ES Trade-Offs and Synergies

3.3.1. Changes in ES Cold and Hotspots

Based on the spatial and temporal differences in the hotspots and cold spots for WC, SC, BC, and CS from 1990 to 2020 (Supplementary S5), the hotspots of WC are located in the northern mountain areas, while cold spots are concentrated on the plains. By 2020, although the area of cold spots on the plains had not decreased, their intensity had weakened. In 1990, the cold spots for SC were mainly distributed in the northern high mountain areas and along riverbanks, significantly reducing along riverbanks by 2010. The hotspots of SC shifted from the central hilly areas to the plains over 30 years. The hotspots for BC increased from the middle and high mountain areas to the plains over 30 years and gradually weakened, with cold spots in the central plains also decreasing over the same period. The hotspots for CSs were concentrated in the central plains and hilly areas in 1990, gradually deteriorating by 2010, but re-emerging as significant hotspots by 2020. Cold spots in 1990 were along riverbanks, extending to the Haba River section by 2010 and eventually transforming into significant hotspots by 2020. From the proportion of cold spots and hotspots of CES (Figure 6), it is evident that highly significant hotspots

dramatically increased in 2010, but reverted to near 2000s levels by 2020. Both significant and less significant hotspots reached their lowest proportion in 2010.

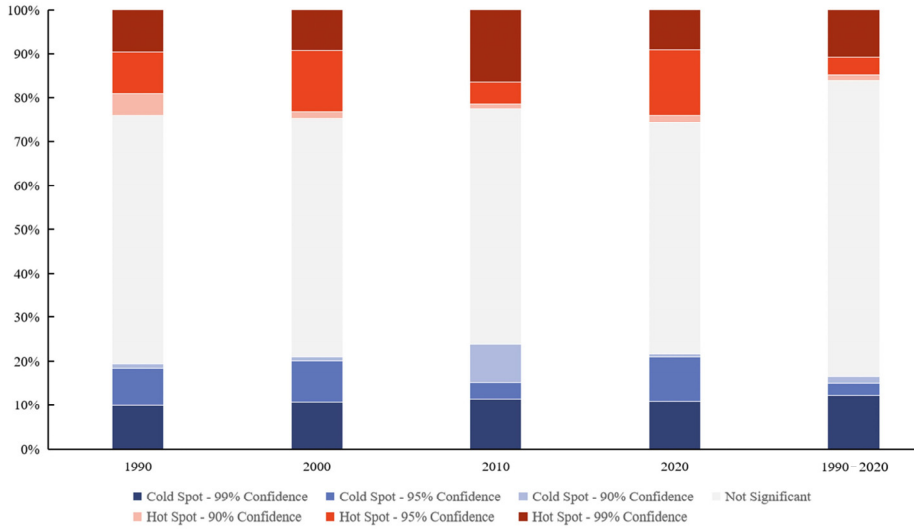


Figure 6. Cold- and hotspot area proportion for comprehensive ES.

Conversely, the area of extremely significant cold spots remained relatively stable, while significant cold spots experienced significant fluctuations around 2010, particularly showing an increase by 2020. Less significant cold spots sharply increased in 2010, but rapidly decreased by 2020, returning to 1990 and 2000 levels. Examination of the trends in hotspots and cold spots from 1990 to 2020 (Figure 7) revealed that significant changes occurred in the northern high mountain areas, middle and low mountain areas, and on the plains. The cold spots in the northern high mountain and middle and low mountain areas decreased, mainly transitioning to non-significant areas. Hotspots were prevalent in the northern middle and low mountain areas and hilly areas, with a significant increase in the hilly areas after 2000. The changes in cold and hotspots were most pronounced between rivers. By 2020, hotspots along riverbanks had strengthened, while cold spots had diminished.

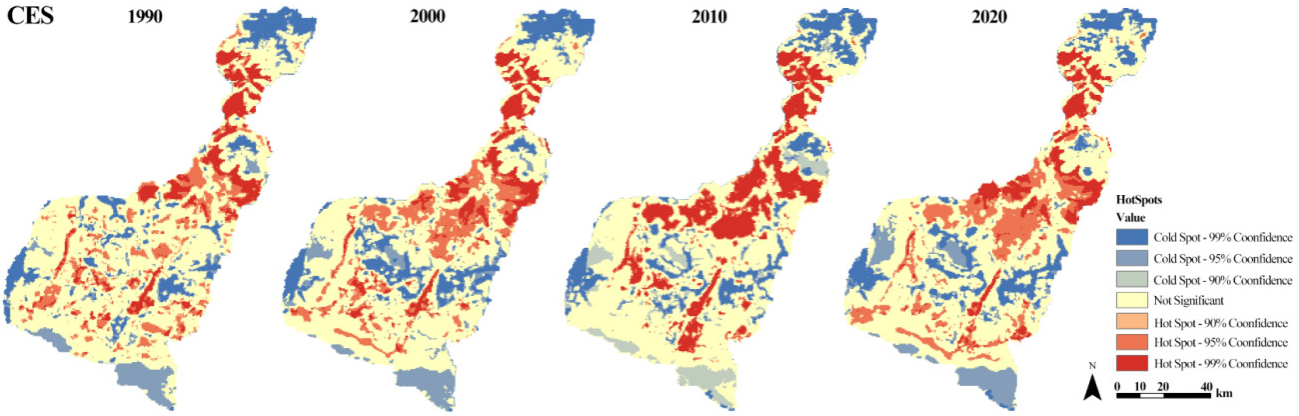


Figure 7. Cold- and hotspot distribution for comprehensive ES from 1990 to 2020.

3.3.2. Spatiotemporal Divergence in Bivariate Trade-Offs and Synergies

- ES trade-offs and Synergies at the overall area scale

The results of the global bivariate Moran's I are shown in Table 4. The strongest positive correlation was between SC and CS, while the strongest negative correlation was between WS and SC. There were significant negative spatial correlations for WC–SC and

BC–WC (both Moran's I value < 0, *p*-value < 0.01), with a decreasing trend in the negative correlation relationship from 1990 to 2020. In addition, there were significant positive correlations for BC–SC, SC–CS, and BC–CS (all Moran's I value > 0, *p*-value < 0.01). The positive correlation for BC–SC showed an increasing trend before 2010, but decreased by 2020. The positive correlation for SC–CS decreased over time, while the positive BC–CS correlation decreased annually until it rose again in 2020. The CS–WC relationship was negative in 1990, but turned positive after that, showing an annual increase.

Table 4. ES trade-offs/synergies at the overall area scale.

Moran's I	1990	2000	2010	2020
WC–SC	−0.50	−0.560	−0.414	−0.431
BC–WC	−0.058	−0.104	−0.054	−0.055
CS–WC	−0.076	0.036	0.038	0.193
BC–SC	0.116	0.148	0.158	0.134
SC–CS	0.269	0.227	0.214	0.129
BC–CS	0.110	0.104	0.065	0.113

Note: WC is water conservation, SC is soil conservation, BC is biodiversity conservation, and CS is carbon storage.

- ES Trade-offs and Synergies at the Grid Scale

The local bivariate Moran's I results illustrate the spatial correlations between different ES using bivariate LISA cluster analysis (Figures 8 and 9). Within the clustering patterns of the four ES, H-H represents high-value synergies between two ESs, L-L signifies low-value synergies between two ESs and H-L, and L-H denotes trade-offs between two ESs. Over the past 30 years, the H-H areas between WC and SC have mainly been concentrated in the mid-low mountain areas and on the plains, with the area remaining relatively stable. The H-L areas were predominantly in the high mountain areas and on the plains: the area has remained stable in the mountains, but there has been a continuous decrease on the plains. The L-H areas have been prominently concentrated on the plains, with a stable area, but there was an increase in 2010.

For BC–WC, the H-H areas are mainly in the mid-low mountains, with the area remaining stable. The L-L areas are concentrated in the upper parts of the plains, with the area stabilizing. The H-L areas are focused on the plains, with the area stabilizing, and there was a transition from H-L to non-significant areas after 2000 in parts of the downstream section of the Haba River. The L-H areas are concentrated in the mid-high mountains, remaining relatively stable, but showing a slight increase by 2020.

For CS–WC, the H-H areas are primarily concentrated in the mid-low mountains, with a stable area. The L-L area is focused on the upper and southern parts along the riverbanks on the plains, showing a generally increasing trend, but a slight decline by 2020. The H-L areas are predominantly concentrated on the plains, with a decreasing area yearly, especially along the southern riverbanks, transitioning to L-L and non-significant areas. The L-H areas are concentrated in the mid-high mountainous regions, showing an increasing trend, with a slight decline by 2020.

For BS–SC, the H-H areas are mainly concentrated on the plains and in hilly areas, stable across much of the area, but with a relatively significant increase by 2000. The L-L areas are concentrated in the mid-high mountains and are stable. The H-L areas focus on mid-high mountains and are stable. The L-H areas are mainly concentrated on the plains, showing a slight overall decline.

For SC–CS, the H-H areas are primarily concentrated in the mid-low mountains, hilly areas, and on the plains, with the proportion increasing until 2010, then transitioning to non-significant areas by 2020. The L-L areas are mainly concentrated in the mid-high mountains, with the proportion increasing until 2010, but by 2020, there was a significant decline, transitioning to non-significant areas. The H-L areas are focused on the plains, showing an increasing trend with enhanced regional connectivity. The L-H areas are mainly

concentrated in the mid-low mountains and on the plains along riverbanks, with the area showing a slight decline, but with an increase in the mid-low mountain areas by 2020.

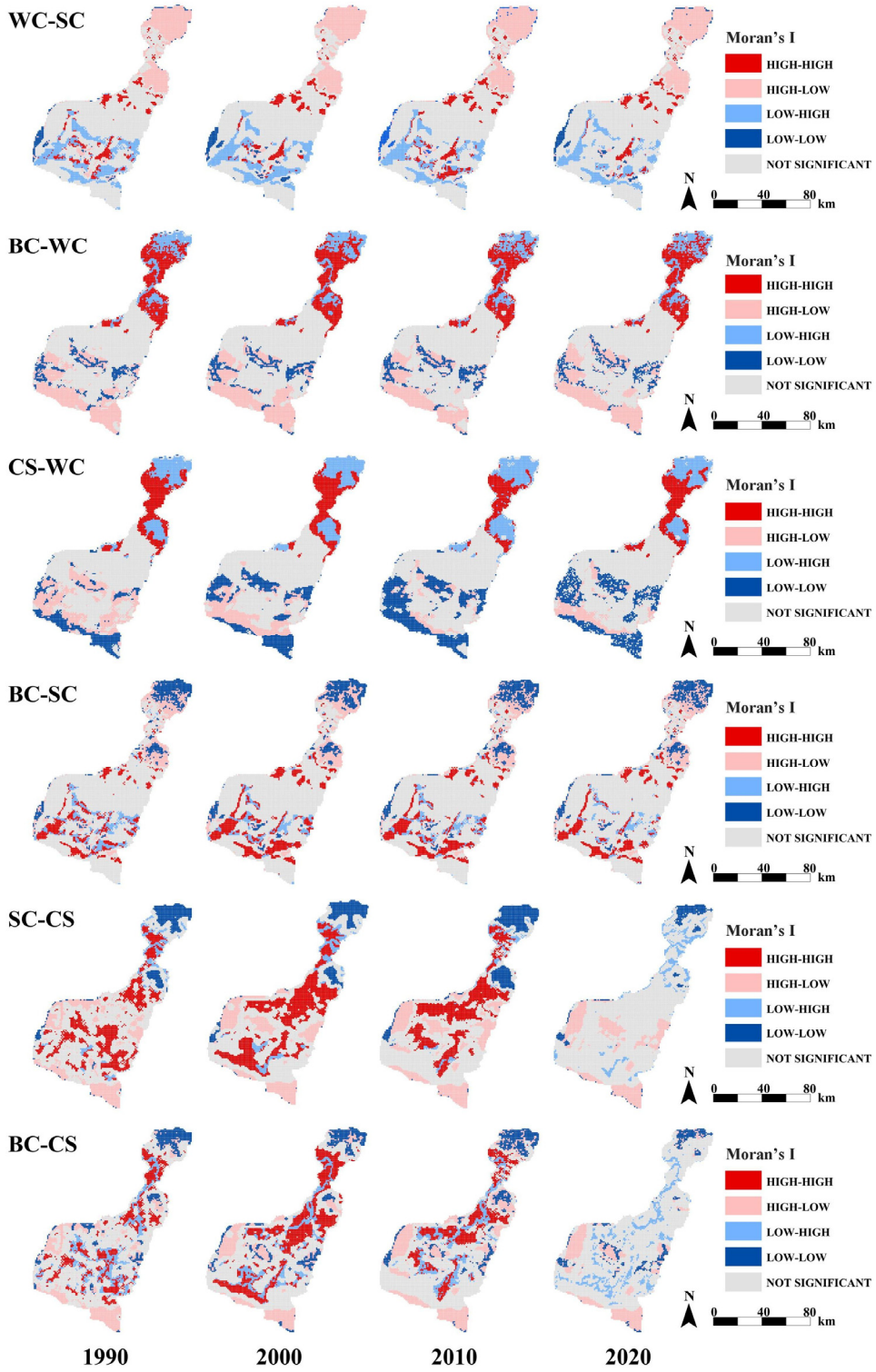


Figure 8. The trade-offs/synergies between pairwise ES on the grid scale. WC is water conservation, SC is soil conservation, BC is biodiversity conservation, and CS is carbon storage.

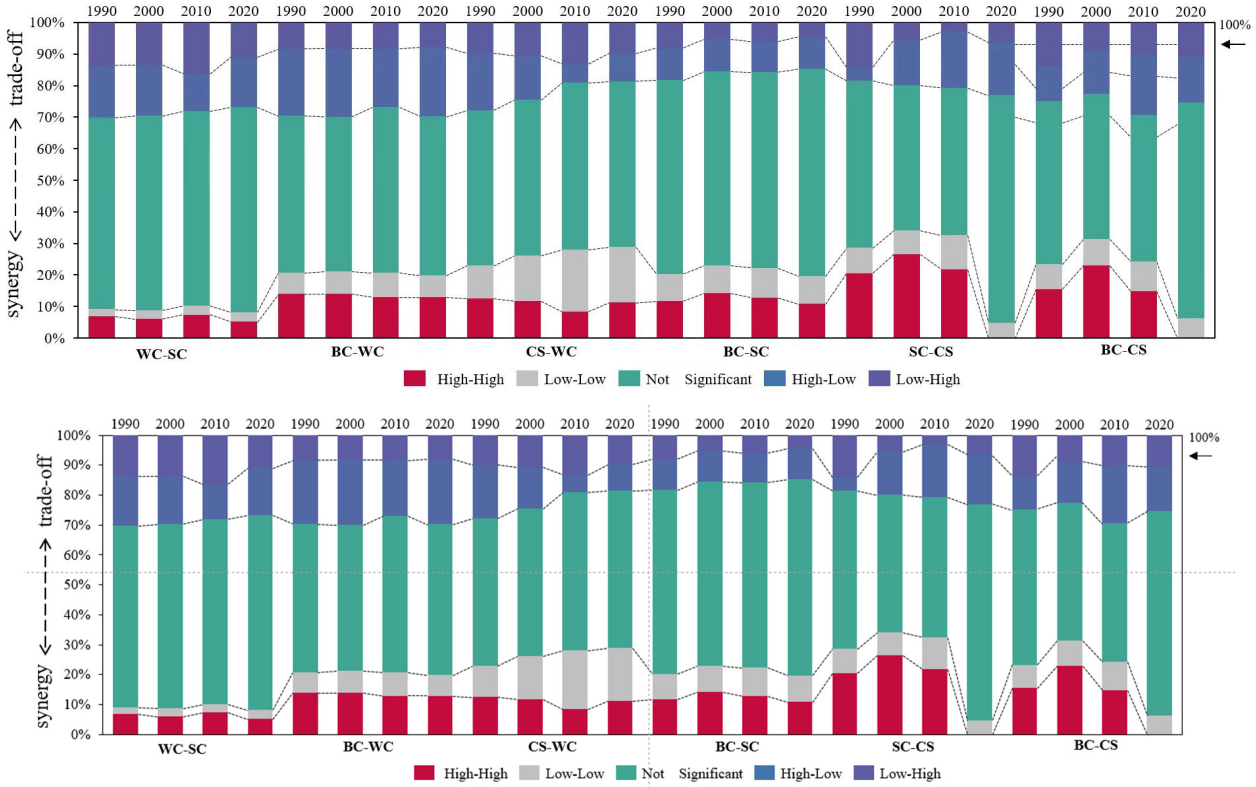


Figure 9. Trade-offs and synergies area proportions of six pairs of ESs on a grid scale. WC is water conservation, SC is soil conservation, BC is biodiversity conservation, and CS is carbon storage.

In Figures 8 and 9, it can be observed that between 1990 and 2020, the CS–WC synergy areas increased, while the trade-off areas decreased. The synergy areas were mainly concentrated in the mid-low mountainous areas, the upper plains, and along the southern rivers, while the trade-off areas were primarily found in the plains and mid-high mountainous areas. The trade-off areas for WC–SC and BC–SC decreased, while the synergy areas also reduced, and the non-significant areas increased. The synergy areas were mainly concentrated in the mid-low mountainous areas, plains, hilly regions, and mid-high mountainous areas. In contrast, the synergy areas for SC–CS and BC–CS decreased, while the trade-off areas increased. The SC–CS trade-off areas were primarily concentrated in the plains, mid-low mountainous areas, and riverbanks in the plains, while the BC–CS trade-off areas were mainly located in the mid-low mountainous areas, hilly regions, and plains.

4. Discussion

4.1. Driving Force Analysis of Spatiotemporal Differences in ES

Revealing the primary drivers of spatial heterogeneity in ecosystem services (ES) can assist decision-makers in formulating targeted ecological management measures [65]. Numerous factors influence ES changes, such as land use, vegetation cover, net primary productivity (NPP), meteorological conditions, and socio-economic factors [68]. Existing studies have shown that natural factors significantly impact ESs, and this driving process is complex, exhibiting varied responses across different regions [69]. Since 2000, the implementation of China's Western Development policy has intensified human disturbances and led to significant land-use changes in the basin, resulting in ecological degradation. However, since 2010, a series of ecological protection measures have improved the development of ESs. This shift highlights that ESs significantly declined between 2000 and 2010, while generally improving from 2010 to 2020 (Figure 5). To better understand these dynamics, we selected the years 2010 and 2020 to analyze 17 driving factors in relation to four individual ESs and the composite ecosystem service (CES). Previous studies have identified precipitation, land use, DEM, weather, topography, and vegetation cover as the

primary factors influencing ES spatial heterogeneity [70]. In our study, we found similar spatial patterns among the four ESs, with NPP contributing the most to CES, aligning with findings from other studies [71]. Furthermore, we acknowledge that vegetation in the headwater areas primarily relies on rainfall, while in the desert areas, surface water transforms into groundwater to sustain growth. Although irrigated farmland within the irrigation zones depends heavily on irrigation water, using irrigation water alone does not fully capture the land-use change dynamics across the entire basin. To address this, we used per capita arable land as a proxy for irrigation water use in our analysis, which adequately reflects the influence of irrigation on land-use change without the need to include irrigation water volume directly in the correlation analysis for the entire basin.

In Figure 10, it can be observed that among the natural factors, the synergy between CES and precipitation, DEM, slope, soil erosion, and NDVI is strengthening, while the relationship with temperature (TEM) has shifted from synergy to trade-off. The trade-off relationship between CES and ET, runoff, and land type is also increasing. Among the social factors, the synergy between CES and population density, per cultivated area, livestock density, and distance to roads is strengthening, while the trade-off with distance to rivers is decreasing. Additionally, the relationship between CES and GDP has shifted from trade-off to synergy. Comparing 2010 and 2020, the synergy between CES and NPP has declined, which is related to the observed transition from forested and shrubland areas to grasslands. Overall, despite increasing drought, ecological conditions improved, boosting agriculture, livestock farming, and eco-tourism, leading to the GDP of the basin continuing to increase. The spatial pattern of BC is most influenced by its distance to roads and other natural factors, reflecting China's protective afforestation policies, with increasing biodiversity observed [72]. The per cultivated area will undoubtedly impact the spatial patterns of CS and BC. Livestock density is crucial for SC, but has a minor overall impact. However, its synergies increased from 2010 to 2020, reflecting China's ecological management policies [26], such as rotational grazing, a ban on grazing, returning farmlands to grasslands, ecological compensation, forage base construction, and water resource management. These measures limited the ecological damage caused by grazing activities, enhancing the most influential natural factor, NPP, on CSs. This indicates that China's ecological management policies have shifted the trade-offs towards synergies or increased the synergies, effectively promoting overall improvement in ESs.

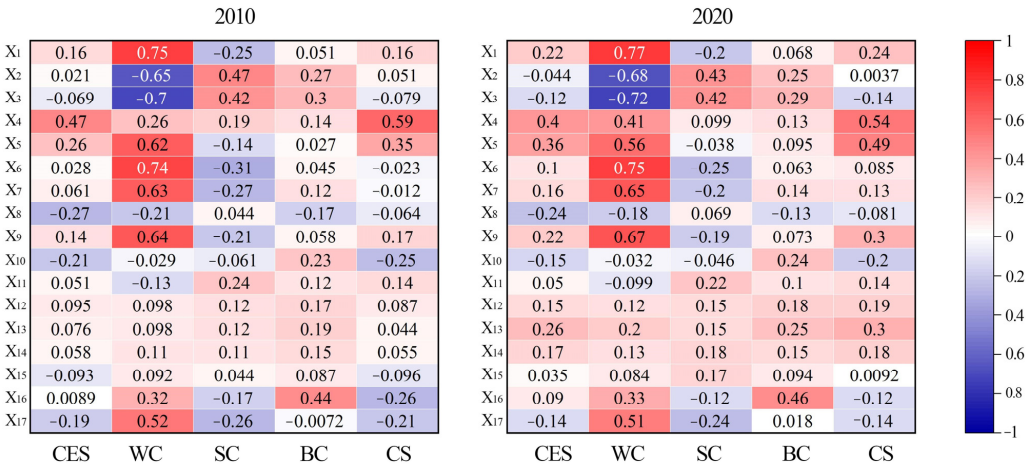


Figure 10. Results of correlations among the 17 drivers, the four key ESs, and CES in the basin for 2010–2020. (1) ESs: WC (water conservation), SC (soil conservation), BC (biodiversity conservation), CS (carbon storage); (2) driving factors: X1 (PRE), X2 (TEM), X3 (ET), X4 (NPP), X5 (NDVI), X6 (DEM), X7 (slope), X8 (surface runoff), X9 (soil erosion), X10 (soil type), X11 (comprehensive index of land-use degree), X12 (population density), X13 (per cultivated area), X14 (livestock density), X15 (GDP), X16 (distance to road), and X17 (distance to river).

4.2. Pathways and Guidance for Enhancing ESs

To depict accurately the spatial heterogeneity of the study area and reveal the trade-offs in arid areas, we explored the interactions of the four ESs at the grid scale, aiming to provide more reasonable suggestions for ecological conservation and the development of agriculture and animal husbandry. First, we studied and determined the spatial distribution characteristics of the cold spots and hotspots for CES from 1990 to 2020 (Figure 11b). Over the 30 years, the hotspots (areas with improved functions) were mainly concentrated in the middle and high mountain areas, hilly areas, and the downstream areas on both sides of the Haba River and along the banks of the Irtysh River. Cold spots (areas with decreased functions) were predominantly focused in the middle and low mountain areas and the upper parts of riverbanks on oasis plains. Second, we qualitatively compared the trade-offs/synergies between ESs using bivariate spatial correlation analysis. Existing studies have shown that the ESs of carbon and water cycles in arid areas are interdependent [62]. The results of this study indicate that CS contributes most to the overall ecological function in the study area (Figure 11a). Enhancing the CS function will promote the overall improvement of ESs, requiring us to pay more attention to the impacts of NPP, NDVI, and land types. The contribution of BC is next in line. Conducting protective afforestation on both sides of roads can reduce the impact on biodiversity in arid areas. The contribution of SC is decreasing over time, mainly influenced positively by TEM and ET, indicating that drought conditions are intensifying.

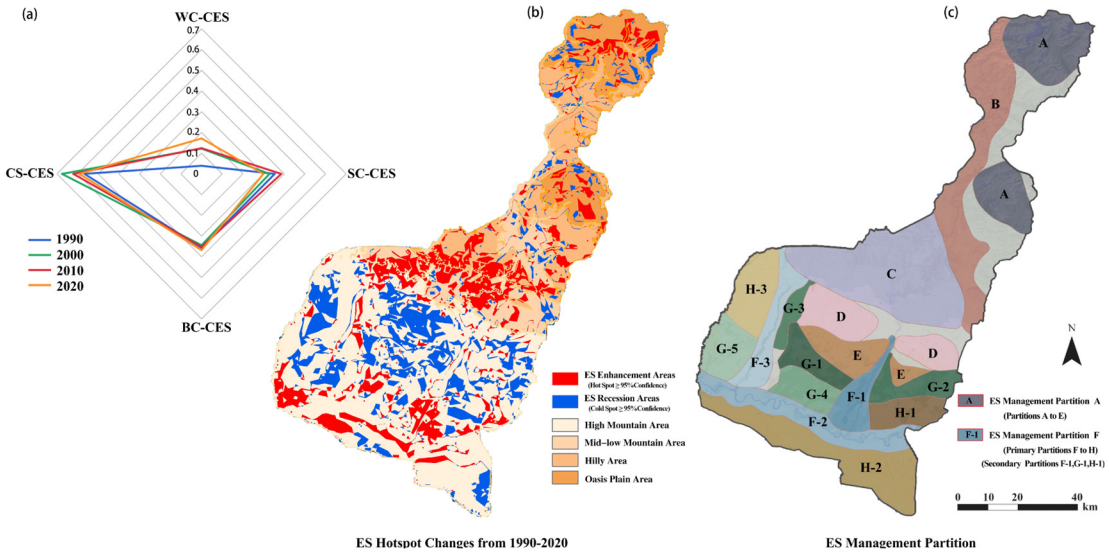


Figure 11. Spatial characteristics and contribution analysis of the hot and cold spots of ecological service functions. (**a**) ES contribution to CES, (**b**) CES cold- and hotspot changes from 1990 to 2020, (**c**) ecological management partition. WC is water conservation, SC is soil conservation, BC is biodiversity conservation, CS is carbon storage, and CES is the comprehensive ES.

The high mountain area (A zone) is a hotspot for CES (enhanced functionality) and also serves as a trade-off area (H-L) for WC–SC. This is because the mountain area has relatively higher precipitation and lower evaporation, making it a significant area for water conservation. However, influenced by DEM and slope, its soil conservation capabilities are low. The mid-low mountain area (B zone) is a cold spot for CES (weakened functionality) and is a high-value synergistic area (H-H) for WC–SC. The hilly area (C zone) is a hotspot for CES (enhanced functionality) and is also a high-value synergistic area (H-H) for WC–SC. Overall, the ESs in the mountain areas are improving. Optimizing grazing activities, controlling livestock numbers appropriately, developing high-yield feed areas in the plains, promoting grassland agriculture, and preventing grassland degradation caused by excessive grazing are recommended [23]. This could also increase the economic income of herdsmen (as shown in Figures 8 and 11b).

The CES of the Oasis Plain has undergone significant changes, with pronounced hotspots and cold spots emerging. It acts as a trade-off area (L-H) for WC–SC. This is due to the relatively low precipitation, rising temperature, increased evaporation, and gentle terrain of the plains. As a result, the SC function is enhanced while the WC function declines. In the D zone of the plain, there is a shift in land types from grassland and sparse grassland to cultivated land. The cultivated area is expanding while its water retention capacity is decreasing. Regarding the CS–WC function relationship, the low-value synergistic areas are increasing (L-L), while the balancing areas are decreasing (H-L), indicating overall ecological degradation in the study area (as shown in Figures 8 and 11). The E zone is predominantly cultivated land, with the CES function declining. Therefore, in the future, the area should carefully develop cultivated land, strictly implement the basic farmland protection policy, and strictly control any expansion of cultivated land. Alongside preserving high-quality farmland, efforts should be made to improve water resource utilization efficiency, manage the scale of oasis areas sensibly, and transition towards more efficient agriculture. This can be achieved by enhancing soil fertility, increasing crop yields, expanding pasture establishment, and fostering agricultural development [73].

Over the three decades, on the plains, zones F-1, F-2, G-3, and G-4 are generally considered hotspot areas (Figures 8 and 11). They also act as high-value synergistic areas for SC–CS (H-H), indicating a positive trend for development in ecological functions. The enhancement of ESs along the Haba River and the Irtysh River suggests that since 2010, ES functionality has generally stabilized with the implementation of China's ecological civilization construction and local reservoir ecological scheduling. In the future, efforts should continue to strengthen the scheduling of ecological reserves to enhance ES functionality. Conversely, the G-1, G-2, and G-5 zones are cold spots, indicating a decline in ecosystem functionality. These are areas that require strengthened ecological management. It is recommended that effective water resource management methods are established to maintain consistent water resource management, to link water from the eastern Berezik River with that from the western Haba River, to construct an ecological river channel network between grasslands and wetlands on the plains, and to adopt infiltrating irrigation [74]. According to the phenological rhythm, water should be replenished in grasslands and wetlands (in the G-1, G-2, G-3, G-4, and G-5 zones) to promote overall ES improvement. Continuous ecological scheduling should be maintained in the F-1 and F-2 zones, ecological scheduling should be increased in the F-3 zone, ecosystem service functions should be further enhanced, precision watering for grasslands and wetlands should be implemented, and vegetation cover should be increased on the oasis plains.

In the desert zones of the plains (zones H-1, H-2, H-3), desertification is increasing, primarily due to the conversion of sparse grasslands and grasslands into desert areas. However, since 2010, the rate of desertification has slowed. There appears to be a balanced relationship (H-L) for both SC–CS and BC–CS. Establishing a comprehensive ecological warning and monitoring system to prevent further degradation of sparse grasslands is recommended. The study indicates that appropriately converting desert areas back to grasslands can contribute to the overall stability of ESs [23]. It is advisable to improve the water conditions between the desert and the edges of grasslands and sparse grasslands and establish an effective windbreak and sand fixation network to prevent the spread of desertification.

The study has revealed the driving factors behind the spatiotemporal variations in ESs, finely depicted the spatial heterogeneity of ES functions, and systematically disclosed the trade-offs and synergies in ESs across different areas of the Haba River Basin, where the increase in cultivated land has intensified the demand for irrigation water, designating these areas as high-water-consumption zones. This heightened demand often competes with the water needs of other ecosystems, leading to ecosystem degradation and a reduction in CES. As a result, water scarcity is a critical factor limiting improvements in these regions. However, the study emphasizes the importance of effective water resource management strategies, such as ecological water replenishment initiatives, to maintain

ecosystem stability, facilitate the transition from areas of trade-offs to areas of synergies, and ensure the proper functioning of ecosystem services. These findings provide valuable insights for the precise and effective management of arid regions, particularly in areas like the Tarim River Basin, the Aral Sea Basin in Central Asia, and regions in Africa where ecosystems are transitioning from trade-offs to synergies [27].

5. Conclusions

It is crucial to understand ES trade-offs and synergies in the Haba River Basin to enhance ES regional capacity, reduce ecological function conflicts, and achieve long-term sustainable development. Strengthening ecological management and transitioning from trade-offs to synergies in the management of ESs in arid areas can effectively improve the ecological environment and economic sustainability, guiding ecological and socio-economic sustainable development in arid areas. From 1990 to 2020, due to water resource management policies, including ecological scheduling and the construction of ecological canal systems, there was a positive trend in the development of land and water resources. The CS function showed a trend of increasing, then decreasing, and increasing again. The high-value areas of CS on the plains are concentrated in the Haba River and Irtysh River basins, showing an overall improvement in ES. Temporally and spatially, ESs have a clear dependency on the trade-off and synergistic interactions. The relationship between CS and WC shifted from trade-offs to synergies, while WS–SC and BC–WC generally showed trade-offs. However, at a more detailed spatial scale, different relationships between ES were present in different areas, exhibiting either trade-offs or synergies. To reduce the trade-offs between ES, it is necessary to protect the ecological environment of the Haba River Basin, optimize the cultivated land area, and enhance the level of water resource management in arid areas. To achieve this, the following measures should be taken. (1) Optimize grazing activities in zones A and B, control livestock levels, and develop grassland agriculture by constructing high-yield feed areas on the plains. (2) Establish effective water resource management methods, continue ecological scheduling in zones F-1 and F-2, increase ecological scheduling in zone F-3, establish a connected water system, implement irrigation systems in zones G-1 to G-5, and ensure fine-scale watering for grasslands and wetlands to increase vegetation cover on the oasis plains. (3) Improve the water conditions between the desert areas (H-1, H-2, H-3) and the adjacent grasslands and sparse grasslands on the plains and establish an effective windbreak and sand fixation network. This method can be applied to other regions with similar ecological environments, particularly arid or ecologically vulnerable areas such as Africa and Central Asia. By promoting this spatial analysis method, other researchers can replicate and extend the research in various geographic settings, thus advancing global sustainable ecosystem management.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/rs16214115/s1. Supplementary S1: Specific evaluation indicators for each ecosystem service; Supplementary S2: Driving factor selection; Supplementary S3: Figures and tables of land-use/cover data; Supplementary S4: Spatial and temporal distribution characteristics of ES; Supplementary S5: Spatiotemporal variation of ES cold and hot spots; Supplementary S6: ES Trade-off/synergy.

Author Contributions: Y.X.: conceptualization, methodology, project administration, validation, writing—original draft. X.S.: methodology, software, validation, visualization. M.D.: conceptualization, methodology, writing—review and editing. T.B.: conceptualization, methodology. W.T.: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the National Key R&D Program Project of China (2023YFC-3206700) and the National Natural Science Foundation of China (52179025).

Data Availability Statement: The authors do not have permission to share data.

Conflicts of Interest: The authors declare that there are no known competing financial interests or personal relationships that could have influenced or appeared to influence any work that is reported in this paper.

References

1. Finlayson, C.M. Millennium Ecosystem Assessment. In *The Wetland Book*; Finlayson, C.M., Everard, M., Irvine, K., McInnes, R.J., Middleton, B.A., Van Dam, A.A., Davidson, N.C., Eds.; Springer Netherlands: Dordrecht, The Netherlands, 2016; pp. 1–5. [CrossRef]
2. Abson, D.J.; Von Wehrden, H.; Baumgärtner, S.; Fischer, J.; Hanspach, J.; Härdtle, W.; Heinrichs, H.; Klein, A.M.; Lang, D.J.; Martens, P.; et al. Ecosystem services as a boundary object for sustainability. *Ecol. Econ.* **2014**, *103*, 29–37. [CrossRef]
3. Costanza, R.; d'Arge, R.; de Groot, R.; Farber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
4. Bateman, I.J.; Harwood, A.R.; Mace, G.M.; Watson, R.T.; Abson, D.J.; Andrews, B.; Binner, A.; Crowe, A.; Day, B.H.; Dugdale, S.; et al. Bringing Ecosystem Services into Economic Decision-Making: Land Use in the United Kingdom. *Science* **2013**, *341*, 45–50. [CrossRef] [PubMed]
5. Srivathsa, A.; Vasudev, D.; Nair, T.; Chakrabarti, S.; Chanchani, P.; DeFries, R.; Deomurari, A.; Dutta, S.; Ghose, D.; Goswami, V.R.; et al. Prioritizing India's landscapes for biodiversity, ecosystem services and human well-being. *Nat. Sustain.* **2023**, *6*, 568–577. [CrossRef]
6. Lee, H.; Lautenbach, S. A quantitative review of relationships between ecosystem services. *Ecol. Indic.* **2016**, *66*, 340–351. [CrossRef]
7. Foley, J.A.; DeFries, R.; Asner, G.P.; Barford, C.; Bonan, G.; Carpenter, S.R.; Chapin, F.S.; Coe, M.T.; Daily, G.C.; Gibbs, H.K.; et al. Global consequences of land use. *Science* **2005**, *309*, 570–574. [CrossRef]
8. Qiu, J.; Carpenter, S.R.; Booth, E.G.; Motew, M.; Zipper, S.C.; Kucharik, C.J.; Loheide Ii, S.P.; Turner, M.G. Understanding relationships among ecosystem services across spatial scales and over time. *Environ. Res. Lett.* **2018**, *13*, 054020. [CrossRef]
9. Seppelt, R.; Dormann, C.F.; Eppink, F.V.; Lautenbach, S.; Schmidt, S. A quantitative review of ecosystem service studies: Approaches, shortcomings and the road ahead. *J. Appl. Ecol.* **2011**, *48*, 630–636. [CrossRef]
10. Liang, J.; Li, S.; Li, X.; Li, X.; Liu, Q.; Meng, Q.; Lin, A.; Li, J. Trade-off analyses and optimization of water-related ecosystem services (WRESs) based on land use change in a typical agricultural watershed, southern China. *J. Clean. Prod.* **2021**, *279*, 123851. [CrossRef]
11. Frank, S.; Fürst, C.; Witt, A.; Koschke, L.; Makeschin, F. Making use of the ecosystem services concept in regional planning—Trade-offs from reducing water erosion. *Landsc. Ecol* **2014**, *29*, 1377–1391. [CrossRef]
12. Feng, Q.; Zhao, W.; Fu, B.; Ding, J.; Wang, S. Ecosystem service trade-offs and their influencing factors: A case study in the Loess Plateau of China. *Sci. Total Environ.* **2017**, *607–608*, 1250–1263. [CrossRef] [PubMed]
13. Lu, Y.; Yang, Y.; Sun, B.; Yuan, J.; Yu, M.; Stenseth, N.C.; Bullock, J.M.; Obersteiner, M. Spatial variation in biodiversity loss across China under multiple environmental stressors. *Sci. Adv.* **2020**, *6*, eabd0952. [CrossRef] [PubMed]
14. Mbaabu, P.R.; Olago, D.; Gichaba, M.; Eckert, S.; Eschen, R.; Oriaso, S.; Choge, S.K.; Linders, T.E.W.; Schaffner, U. Restoration of degraded grasslands, but not invasion by Prosopis juliflora, avoids trade-offs between climate change mitigation and other ecosystem services. *Sci. Rep.* **2020**, *10*, 20391. [CrossRef] [PubMed]
15. Berdugo, M.; Delgado-Baquerizo, M.; Soliveres, S.; Hernández-Clemente, R.; Zhao, Y.; Gaitán, J.J.; Gross, N.; Saiz, H.; Maire, V.; Lehmann, A.; et al. Global ecosystem thresholds driven by aridity. *Science* **2020**, *367*, 787–790. [CrossRef]
16. DeFries, R.; Nagendra, H. Ecosystem management as a wicked problem. *Science* **2017**, *356*, 265–270. [CrossRef]
17. Hou, Y.; Chen, Y.; Ding, J.; Li, Z.; Li, Y.; Sun, F. Ecological Impacts of Land Use Change in the Arid Tarim River Basin of China. *Remote Sens.* **2022**, *14*, 1894. [CrossRef]
18. Tully, K.; Sullivan, C.; Weil, R.; Sanchez, P. The State of Soil Degradation in Sub-Saharan Africa: Baselines, Trajectories, and Solutions. *Sustainability* **2015**, *7*, 6523–6552. [CrossRef]
19. Geng, W.; Li, Y.; Zhang, P.; Yang, D.; Jing, W.; Rong, T. Analyzing spatio-temporal changes and trade-offs/synergies among ecosystem services in the Yellow River Basin, China. *Ecol. Indic.* **2022**, *138*, 108825. [CrossRef]
20. Locatelli, B.; Imbach, P.; Wunder, S. Synergies and trade-offs between ecosystem services in Costa Rica. *Environ. Conserv.* **2014**, *41*, 27–36. [CrossRef]
21. Wang, Y.; Zhao, J.; Fu, J.; Wei, W. Effects of the Grain for Green Program on the water ecosystem services in an arid area of China—Using the Shiyang River Basin as an example. *Ecol. Indic.* **2019**, *104*, 659–668. [CrossRef]
22. Bai, Y.; Ochuodho, T.O.; Yang, J. Impact of land use and climate change on water-related ecosystem services in Kentucky, USA. *Ecol. Indic.* **2019**, *102*, 51–64. [CrossRef]
23. Fu, Q.; Li, B.; Hou, Y.; Bi, X.; Zhang, X. Effects of land use and climate change on ecosystem services in Central Asia's arid regions: A case study in Altay Prefecture, China. *Sci. Total Environ.* **2017**, *607–608*, 633–646. [CrossRef] [PubMed]
24. Raudsepp-Hearne, C.; Peterson, G.D.; Bennett, E.M. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 5242–5247. [CrossRef] [PubMed]
25. Li, Y.; Luo, H. Trade-off/synergistic changes in ecosystem services and geographical detection of its driving factors in typical karst areas in southern China. *Ecol. Indic.* **2023**, *154*, 110811. [CrossRef]

26. Fu, Q.; Li, B.; Yang, L.; Wu, Z.; Zhang, X. Ecosystem Services Evaluation and Its Spatial Characteristics in Central Asia's Arid Regions: A Case Study in Altay Prefecture, China. *Sustainability* **2015**, *7*, 8335–8353. [CrossRef]
27. White, K.D. Nature–Society Linkages in the Aral Sea Region. *J. Eurasian Stud.* **2013**, *4*, 18–33. [CrossRef]
28. Wangai, P.W.; Burkhard, B.; Müller, F. A review of studies on ecosystem services in Africa. *Int. J. Sustain. Built Environ.* **2016**, *5*, 225–245. [CrossRef]
29. Huang, W.; Duan, W.; Nover, D.; Sahu, N.; Chen, Y. An integrated assessment of surface water dynamics in the Irtysh River Basin during 1990–2019 and exploratory factor analyses. *J. Hydrol.* **2021**, *593*, 125905. [CrossRef]
30. He, B.; Chang, J.; Wang, Y.; Wang, Y.; Zhou, S.; Chen, C. Spatio-temporal evolution and non-stationary characteristics of meteorological drought in inland arid areas. *Ecol. Indic.* **2021**, *126*, 107644. [CrossRef]
31. Yang, Z.; Li, B.; Nan, B.; Dai, X.; Peng, C.; Bi, X. A methodological framework for assessing pastoral socio-ecological system vulnerability: A case study of Altay Prefecture in Central Asia. *Sci. Total Environ.* **2023**, *862*, 160828. [CrossRef]
32. Zeng, Y.-F.; Zhang, J.-G.; Duan, A.-G.; Abuduhamiti, B. Genetic structure of Populus hybrid zone along the Irtysh River provides insight into plastid-nuclear incompatibility. *Sci. Rep.* **2016**, *6*, 28043. [CrossRef] [PubMed]
33. Hanchu, L.; Jie, F.; Baoyin, L.; Li, W.; Qin, Q. Practical Exploration of Ecological Restoration and Management of the Mountains-Rivers-Forests-Farmlands-Lakes-Grasslands System in the Irtysh River Basin in Altay, Xinjiang. *Jore* **2021**, *12*, 766–776. [CrossRef]
34. Xue, C.; Chen, X.; Xue, L.; Zhang, H.; Chen, J.; Li, D. Modeling the spatially heterogeneous relationships between tradeoffs and synergies among ecosystem services and potential drivers considering geographic scale in Bairin Left Banner, China. *Sci. Total Environ.* **2023**, *855*, 158834. [CrossRef] [PubMed]
35. Duraiappah, A.K.; Naeem, S.; Agardy, T.; Ash, N.J.; Cooper, H.D.; Diaz, S.; Faith, D.P.; Mace, G.; McNeely, J.A.; Mooney, H.A.; et al. *Ecosystems and Human Well-Being: Biodiversity Synthesis*; A Report of the Millennium Ecosystem Assessment; World Resources Institute: Washington, DC, USA, 2005.
36. Qin, H.; Chen, Y. Spatial non-stationarity of water conservation services and landscape patterns in Erhai Lake Basin, China. *Ecol. Indic.* **2023**, *146*, 109894. [CrossRef]
37. Bai, J.; Zhou, Z.; Li, J.; Liu, T.; Zhu, Q.; Zheng, T. Predicting soil conservation service in the Jinghe River Basin under climate change. *J. Hydrol.* **2022**, *615*, 128646. [CrossRef]
38. Kang, J.; Zhang, X.; Zhu, X.; Zhang, B. Ecological security pattern: A new idea for balancing regional development and ecological protection. A case study of the Jiaodong Peninsula, China. *Glob. Ecol. Conserv.* **2021**, *26*, e01472. [CrossRef]
39. Zhang, T.; Cao, G.; Cao, S.; Zhang, X.; Zhang, J.; Han, G. Dynamic assessment of the value of vegetation carbon fixation and oxygen release services in Qinghai Lake basin. *Acta Ecol. Sin.* **2017**, *37*, 79–84. [CrossRef]
40. Yang, L.; Suo, M.; Gao, S.; Jiao, H. Construction of an Ecological Network Based on an Integrated Approach and Circuit Theory: A Case Study of Panzhou in Guizhou Province. *Sustainability* **2022**, *14*, 9136. [CrossRef]
41. Wu, L.; Fan, F. Assessment of ecosystem services in new perspective: A comprehensive ecosystem service index (CESI) as a proxy to integrate multiple ecosystem services. *Ecol. Indic.* **2022**, *138*, 108800. [CrossRef]
42. Gong, S.H.; Xiao, Y.; Zheng, H.; Xiao, Y.; Ouyang, Z.Y. Spatial patterns of ecosystem water conservation in China and its impact factors analysis. *Acta Ecol. Sin.* **2017**, *37*, 2455–2462.
43. Zhang, L.; Walker, G.R.; Dawes, W.R. Water balance modelling: Concepts and applications. In *Handbook of Environmental Materials Management*; Springer: Cham, Switzerland, 2002.
44. Yu, K. *Regional Ecological Security Patterns: The Beijing Case*, 1st ed.; Zhongguo Jian Zhu Gong Ye Chu Ban She: Beijing, China, 2012.
45. Yu, K. Landscape ecological security patterns in biological conservation. *Acta Ecol. Sin.* **1999**, *19*, 8–15.
46. Lambeck, R.J. Focal Species: A Multi-Species Umbrella for Nature Conservation. Especies Focales: Una Sombrilla Multiespecifica para Conservar la Naturaleza. *Conserv. Biol.* **1997**, *11*, 849–856. [CrossRef]
47. Lindenmayer, D.B.; Manning, A.D.; Smith, P.L.; Possingham, H.P.; Fischer, J.; Oliver, I.; McCarthy, M.A. The Focal-Species Approach and Landscape Restoration: A Critique. *Conserv. Biol.* **2002**, *16*, 338–345. [CrossRef]
48. Erdenechimeg, B.; Purev-Ochir, G.; Gungaa, A.; Terbish, O.; Zhao, Y.; Guo, Y. Migration Pattern, Habitat Use, and Conservation Status of the Eastern Common Crane (Grus grus lilfordi) from Eastern Mongolia. *Animals* **2023**, *13*, 2287. [CrossRef] [PubMed]
49. Månsson, J.; Nilsson, L.; Hake, M. Territory size and habitat selection of breeding Common Cranes (Grus grus) in a boreal landscape. *Ornis Fenn.* **2013**, *90*, 65–72. [CrossRef]
50. Duan, Y.; Liu, Q.; Lei, Y.; Li, J.; Liu, W.; Li, Z.; Wang, R. Habitat selection of overwintering common crane (Grus grus) based on individuals tracking by satellite technology. *Chin. J. Ecol.* **2020**, *39*, 2392–2399. [CrossRef]
51. Kong, D.; Luo, W.; Liu, Q.; Li, Z.; Huan, G.; Zhang, J.; Yang, X. Habitat use, preference, and utilization distribution of two crane species (Genus: Grus) in Huize National Nature Reserve, Yunnan–Guizhou Plateau, China. *PeerJ* **2018**, *6*, e5105. [CrossRef]
52. Li, D.; Jiang, Z.; Wang, Z. Activity Patterns and Habitat Selection of the Przewalski"s Gazelle (Procapra przewalskii) in the Qinghai Lake Region. *Acta Theriol. Sin.* **1999**, 18–25. [CrossRef]
53. Liang, D.; Li, C. Habitat Suitability, Distribution Modelling and GAP Analysis of Przewalski"s Gazelle Conservation. *Animals* **2024**, *14*, 149. [CrossRef]
54. Cornelis, D.; Kan, E.; Gond, V.; Cesaro, J.-D.; Peltier, R. Estimation of the red deer population and its impact on the Tugay forest ecosystem in the Lower Amu Darya State Biosphere Reserve, Uzbekistan. *Bois For. Des Trop.* **2020**, *346*, 65–78. [CrossRef]

55. Tumur, A.; Abliz, D.; Halik, M. Habitat dynamics and its influence on the genetic diversity of Tarim red deer (Cervus elaphus yarkandensis) Xayar population of Xinjiang, China. *Quat. Int.* **2013**, *311*, 140–145. [CrossRef]
56. Zhang, Y.; Zhang, C.; Wang, Z.; Chen, Y.; Gang, C.; An, R.; Li, J. Vegetation dynamics and its driving forces from climate change and human activities in the Three-River Source Region, China from 1982 to 2012. *Sci. Total Environ.* **2016**, *563–564*, 210–220. [CrossRef] [PubMed]
57. Bai, B.; Li, N. Influence of habitat fragmentation on frugivores and their seed dispersal. *Chin. J. Ecol.* **2011**, *30*, 2613.
58. Wu, Q.; Song, J.; Sun, H.; Huang, P.; Jing, K.; Xu, W.; Wang, H.; Liang, D. Spatiotemporal variations of water conservation function based on EOF analysis at multi time scales under different ecosystems of Heihe River Basin. *J. Environ. Manag.* **2023**, *325*, 116532. [CrossRef] [PubMed]
59. Wischmeier, W.H.; Smith, D.D. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning (No. 537)*; Department of Agriculture, Science and Education Administration: Canberra, Australia, 1978; XF2006179521.
60. Cramer, W.; Kicklighter, D.W.; Bondeau, A.; Iii, B.M.; Churkina, G.; Nemry, B.; Ruimy, A.; Schloss, A.L.; ThE. Participants OF. ThE. Potsdam NpP. Model Intercomparison. Comparing global models of terrestrial net primary productivity (NPP): Overview and key results. *Glob. Change Biol.* **1999**, *5*, 1–15. [CrossRef]
61. Ding, T.; Chen, J.; Fang, Z.; Chen, J. Assessment of coordinative relationship between comprehensive ecosystem service and urbanization: A case study of Yangtze River Delta urban Agglomerations, China. *Ecol. Indic.* **2021**, *133*, 108454. [CrossRef]
62. Guo, J.; Xu, H.; Zhang, G.; Yuan, K.; Ling, H. The Enhanced Management of Water Resources Improves Ecosystem Services in a Typical Arid Basin. *Sustainability* **2020**, *12*, 8802. [CrossRef]
63. Anselin, L.; Rey, S.J. *Modern Spatial Econometrics in Practice: A Guide to GeoDa, GeoDaSpace and PySAL*; GeoDa Press: Chicago, IL, USA, 2014.
64. Huang, F.; Zuo, L.; Gao, J.; Jiang, Y.; Du, F.; Zhang, Y. Exploring the driving factors of trade-offs and synergies among ecological functional zones based on ecosystem service bundles. *Ecol. Indic.* **2023**, *146*, 109827. [CrossRef]
65. Jing, H.; Liu, Y.; He, P.; Zhang, J.; Dong, J.; Wang, Y. Spatial heterogeneity of ecosystem services and it's influencing factors in typical areas of the Qinghai-Tibet Plateau: A case study of Nagqu City. *Acta Ecol. Sin.* **2022**, *42*, 2657–2673.
66. Zhuang, D.; Liu, J. Modeling of regional differentiation of land-use degree in China. *Chin. Geograph.Sc.* **1997**, *7*, 302–309. [CrossRef]
67. Canelas, J.V.; Pereira, H.M. Impacts of land-use intensity on ecosystems stability. *Ecol. Model.* **2022**, *472*, 110093. [CrossRef]
68. Liu, J.; Pei, X.; Zhu, W.; Jiao, J.; Wang, Z. Fine grid scale increases or decreases the trade-off effect between ES in mountain protected areas? *Ecol. Indic.* **2023**, *155*, 110905. [CrossRef]
69. Hao, R.; Yu, D.; Wu, J.; Guo, Q.; Liu, Y. Constraint line methods and the applications in ecology. *Chin. J. Plant Ecol.* **2016**, *40*, 1100–1109. [CrossRef]
70. Li, Y.; Liu, W.; Feng, Q.; Zhu, M.; Yang, L.; Zhang, J. Quantitative Assessment for the Spatiotemporal Changes of Ecosystem Services, Tradeoff–Synergy Relationships and Drivers in the Semi-Arid Regions of China. *Remote Sens.* **2022**, *14*, 239. [CrossRef]
71. Wang, X.; Tan, K.; Chen, B.; Du, P. Assessing the Spatiotemporal Variation and Impact Factors of Net Primary Productivity in China. *Sci. Rep.* **2017**, *7*, 44415. [CrossRef]
72. Chidwala, A.; Frimpong, S.; Raman, A. Effect of shelterbelts on the abundance and diversity of Earthworms in pastures in the Central-West Tablelands of New South Wales, Australia. *Int. J. Ecol. Environ. Sci.* **2014**, *40*, 123–130.
73. Xia, N.; Hai, W.; Tang, M.; Song, J.; Quan, W.; Zhang, B.; Ma, Y. Spatiotemporal evolution law and driving mechanism of production–living–ecological space from 2000 to 2020 in Xinjiang, China. *Ecol. Indic.* **2023**, *154*, 110807. [CrossRef]
74. Deng, M.; Huang, Q.; Chang, J.; Huang, S. Large-scale ecological operation research and practice. *J. Hydraul. Eng.* **2020**, *51*, 757–773. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.