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Evaluation of the Gross Ecosystem Product and Analysis of the Transformation Path of "Two Mountains" in Hulunbuir City, China

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Abstract: The objective assessment of ecological systems forms the basis of solving ecological environmental problems. Evaluating the ecosystem status of each county through the gross ecosystem product (GEP) can reveal the value of each ecosystem. In this study, we used the eco-economic method to calculate the GEP and the green gold index (GGI) of 13 counties in Hulunbuir City between 2015 and 2020. The results show that: (1) The GEP of Hulunbuir City in 2020 was 980.025 billion yuan. The GGI was 8.36, which was much higher than the national average. (2) Forestry and pastoral regions were the main contributors to the regulation service. (3) Hulunbuir City had the largest forest value, while the farmland value was the lowest. The most important sources of forest, grassland, wetland, water, and farmland value were Oroqen, Xin Right Banner, Xin Left Banner, Xin Right Banner, and Morin Banner, respectively. Based on our analysis, we found significant results through the transformation of the "Two Mountains" in Erguna, Genhe, and Zhalantun. The other counties in our study must optimize ecological research with respect to the traditional economic model. Our results provide a scientific reference for the application of the "Two Mountains" base in each county.

Keywords: gross ecosystem product (GEP); green gold index (GGI); "Two Mountains" transformation; county territory

Citation: Zhao, N.; Wang, H.; Zhong, J.; Bai, Y.; Yi, S. Evaluation of the Gross Ecosystem Product and Analysis of the Transformation Path of "Two Mountains" in Hulunbuir City, China. *Land* **2023**, *12*, 63. https://doi.org/10.3390/land12010063

Academic Editors: Matteo Convertino and Jie Li

Received: 19 November 2022
Revised: 16 December 2022
Accepted: 19 December 2022
Published: 26 December 2022

1. Introduction

The rapid development of the global economy has negatively affected the ecological environment. Ecological and environmental crises, such as ecosystem function degradation, excessive natural resource consumption, biodiversity reduction, and pollution, have adversely affected the well-being of humans [1]. These global concerns have led to an increased focus on ecological and environmental management and sustainability [2]. Ecological resources not only provide a variety of tangible products but also provide ecosystem services [3]. Assessment of ecosystem status will aid in the sustainable utilization of ecological resources and help in the development of solutions [4]. Since Constanza [5] and Daily [6] published their articles on the value of ecosystem services, numerous scholars have conducted a series of similar studies worldwide [7–11]. As a result of growing research, scholars have proposed the incorporation of ecological benefits into the evaluation systems of economic and social development [12]. Consequently, countries worldwide have started accounting and auditing the value of natural resources. Concepts such as green gross domestic product, system of environmental-economic accounting, and gross economic-ecological product have emerged [13–15]. Ouyang (2013) proposed the concept of the gross ecosystem product (GEP), corresponding to the gross domestic product

(GDP) [16]. GEP is the sum of the final material products and service values provided by ecosystems for human well-being and sustainable economic and social development, including the ecological product value, ecological regulation service value, and ecological culture service value [17]. Thus, the GEP forms an independent ecosystem value accounting system. The evaluation of GEP directly reveals the substantial value of an ecosystem in the study area [18]. Ma [19], Bai [20], and Dong [21] evaluated GEP in China, Yunnan Province, and Ordos City, respectively. County region is the basic administrative unit in China and the micro-subject and key link of ecological civilization construction [22]. Scholars realized the importance of assessing the effectiveness of ecological protection at the county scale, and GEP research is gradually focusing on that scale. You [22], Yu [23], and Pema [24,25] evaluated the GEP of China's Eshan County, the Chenggong District, and Garzê Tibetan Autonomous Prefecture and Xishui County, respectively. However, few studies have compared GEP among counties. Not only can county-scale GEP be used to understand the status of these local ecosystems, but more importantly, the joint effect of comparing GEP among counties plus environmental protection can help improve the GEP at a larger scale. Therefore, this study calculated, compared, and analyzed the GEP of 13 counties in Hulunbuir City and obtained the GEP of Hulunbuir City by summing the GEP of the counties. Compared with a direct accounting of Hulunbuir City GEP, the results of this study have more application value and social significance. By focusing on individual counties, targeted ecological protection measures can be implemented to ultimately improve the ecosystems of the greater Hulunbuir City area, which is one of the innovations of this study.

GEP accounting methods mainly include energy-value and quality-value evaluation methods [26], with the quality-value method being used globally. The GEP accounting process comprises two parts: (1) ecosystem service quality and (2) ecosystem service value [16]. The output of ecological products and the quantity of the ecosystem service function, namely the ecosystem service quality, are calculated through various ecological models. The units of ecosystem service quality are not the same. Accounting for the ecosystem services' value requires transforming the ecosystem service quality into a uniform and directly linear unit [27]. Then, the values can be summed up to obtain the GEP. In previous studies, no uniform standard was developed for this calculation. GEP values are different when different evaluation methods, evaluation indexes, and price parameters are selected for the same region. Jin [28] and Fan [29] both calculated GEP in Guizhou Province, but the methods and indicators of evaluation were different, leading to varied results. These inconsistencies skew our understanding of GEP in a study area. To improve the science, standardization, and operability of GEP accounting, the National Development and Reform Commission of China issued the "GEP Accounting Specification (Trial)" in 2022.

While exploring the replicable, extensible, and demonstrable accounting models of GEP, scholars have promoted the transformation of GEP from an "accounting value" to a "policy point" [30]. Jin [28] incorporated GEP into the evaluation and analysis of ecological compensation performance assessment in Guizhou Province. To better understand how much ecosystem value there is, Dong [21] applied GEP to a comparative analysis of ecological stock and flow in Ordos City, China. Chen [31] studied the coupling relationship between GEP and ecological carrying capacity in Changting County, China, to provide a basis for evaluating the effectiveness of ecological protection. Similarly, Lin [32] applied GEP to identify ecological protection space in the Yangtze River Delta region, which is critical for maintaining regional ecological security. In practice, GEP is primarily studied in combination with GDP, which can provide a theoretical basis for government performance appraisal. The "clear waters and green mountains are as good as mountains of gold and silver" theory (referred to as the "Two Mountains" theory) links GEP with GDP [33]. The "clear waters and green mountains" represent the competitive natural resources and good ecological environment that provide ecological products and services for people's lives and survival. The "gold and silver mountains" represent regional economic conditions and people's livelihood related to income level [34]. The "Two Mountains" theory points out that the natural ecosystem not only has considerable ecological benefits, but the ecological value can also be converted into economic benefits and contribute to human well-being [35]. Quantifying the value of "clear waters and green mountains" is the basis for an efficient transformation from ecological resources to ecological assets and capital, and the GEP can be used to evaluate this value [36]. Ma [19] first used the green gold index (GGI) to link "clear waters and green mountains" with "gold and silver mountains," which is relatively mature in practical application. Cheng [37] and Chen [38] measured the transformation relationship between "clear waters and green mountains" and "gold and silver mountains" in Quzhou City and Ninghai County of Zhejiang Province, respectively, through the GGI, and discussed the transformation path of these "Two Mountains." As the basic unit of the "Two Mountains" theory, the county has the comparative advantages of small size, rapid transformation, and rapid effect [34]. Since 2017, the Ministry of Ecology and Environment has named 136 "Two Mountains" bases, of which the county-scale accounts for up to 75%.

Hulunbuir City is an important ecological barrier in China and a world-class eco-city with unique ecological advantages and capitalization. In recent years, Hulunbuir City has paid more attention to ecological protection, including controlling pollution and restoring ecosystems. However, there has been no quantitative analysis of the number of "ecological properties," the degree of environmental improvements, or the ecological differences among each county in Hulunbuir City. Therefore, referencing the 2022 "GEP Accounting Specification (Trial)," we screened evaluation indicators that best aligned with the ecosystem characteristics of Hulunbuir City so that the GEP would more truly reflect the region's environment and protections. Then, we conducted quantitative GEP analysis of the 13 counties in Hulunbuir City at the end of the 12th Five-Year Plan (2015) and 13th Five-Year Plan (2020) in accordance with the accounting method in the 2022 document. Then, the GGI of each county was calculated according to the GEP results. Finally, based on the GEP and GGI, the transformation path of "Two Mountains" in each county was explored, and the application of the "Two Mountains" base was further promoted in Hulunbuir City and surrounding counties. This study fills the gap of GEP comparative research at the county scale and applies the indicators and methods in the 2022 specification to measure the GEP of 13 counties. This study is an early implementer of the specification and has set an example for similar accounting in other counties. Furthermore, our study of the transformation path of "Two Mountains" at the county level can be replicated in the theoretical and practical research of similar counties in China or even around the world.

2. Materials and Methods

2.1. Study Area

Hulunbuir City (115°31′–126°04′ E, 47°05′–53°20′ N) is located in the northeastern Inner Mongolia Autonomous Region, with a total area of 262,000 km^2, accounting for 21.4% of the total area of Inner Mongolia. It has rich and diverse land resources and types and is characterized by abundant resources, such as grasslands, forests, minerals, water, and biology. Hulunbuir City is famous for "Great Grasslands, Great Forests, Great Wetlands, Great Lakes, and Great Snow." It has been dominated by agriculture and animal husbandry (single-industry areas) and has developed into a regional economy based on the planting, animal husbandry, coal power, coal chemicals, and processing and manufacturing industries, with logistics trade and tourism as important components. The city now has jurisdiction over 14 counties, forming four ecological economic zones according to the landform, land type, and industrial types [39]. Oroqen Autonomous Banner (Oroqen), Yakeshi City (Yakeshi), Genhe City (Genhe), and Erguna City (Erguna) belong to the forestry region. Xin Barag Right Banner (Xin Right Banner), Ewenki Autonomous Banner (Ewenki), Xin Barag Left Banner (Xin Left Banner), and Prairie Chenbarhu Banner (Chen Banner) belong to the pastoral region. Zhalantun City (Zhalantun), Arun Banner, and Daur Autonomous Banner of Morin Dawa (Morin Banner) belong to the agricultural region. Manzhouli City (Manzhouli) and Hailar Area (Hailar) are collectively referred to as the central urban region.

It can be seen in Figure 1 that there are several types of ecosystems in Hulunbuir City, including forests, shrubland, grassland, wetlands, water bodies (including lakes and rivers), and farmland. Among these, the forest ecosystem area is the largest, accounting for 54.77% of Hulunbuir City, mainly distributed in Oroqen, Yakeshi, Erguna, Genhe, Zhalantun, and Ewenki. The grassland ecosystem accounted for 34.43%, which was concentrated in Xin Right Banner, Xin Left Banner, Chen Banner, Ewenki, Hailar, and Manzhouli. The farmland ecosystem is distributed in Morin Banner, Arun Banner, Zhalantun, Oroqen, Yakeshi, Erguna, and other regions in a pattern of large dispersion and small aggregation. The water body ecosystem is mainly distributed in Xin Right Banner, Xin Left Banner, and Morin Banner. The wetland ecosystem is distributed in New Right Banner, Xin Left Banner, and E Banner.

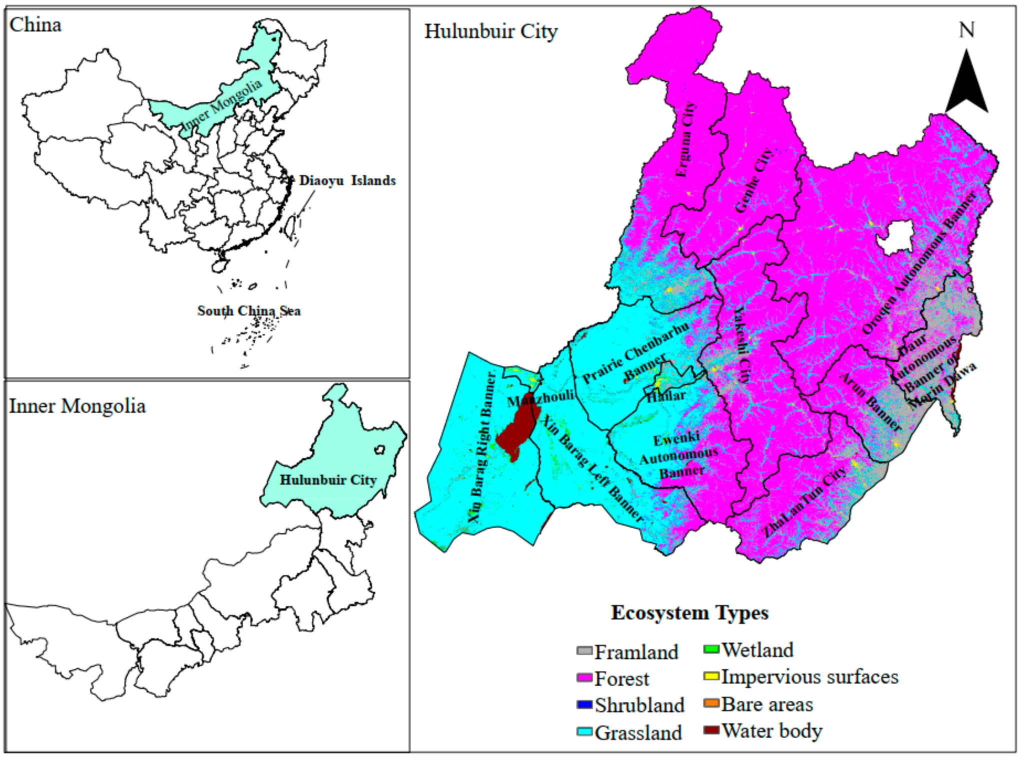


Figure 1. The ecosystem types of the study area (Hulunbuir City, China).

2.2. Methodology

2.2.1. Data Preprocessing

The Land-Use and Land-Cover Change (LUCC) of this study adopted 30 m land-use data released by the Remote Sensing Institute of the Chinese Academy of Sciences. Digital elevation models were obtained from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences. Meteorological data, such as rainfall, surface runoff, and evapotranspiration, were obtained from the Global Land Data Assimilation System and Hulunbuir Meteorological Bureau. Soil data were obtained from the National Tibetan Plateau/Third Pole Environment Data Center. The Net Primary Productivity and Normalized Difference Vegetation Index data were obtained from MOD17 and MOD13 products from the National Aeronautics and Space Administration. Data for the reservoir storage capacity and water resource consumption were obtained from the Hulunbuir Water Resources Bulletin. Social and economic data were all obtained from the statistical yearbook for Hulunbuir City and relevant data from the Statistics Bureau. The prices of all types of products and alternative products were derived from the Forest Ecosystem Service Function Assessment Specifications [40]. The above raster data were formed by stitching and cutting. The data year was the end of the 12th Five-Year Plan (2015) and the end of the 13th Five-Year Plan (2020) of Hulunbuir City.

2.2.2. Assessment Method for Ecosystem Service Quality

Water conservation is the interception and retention of precipitation by the ecosystem, thus increasing the available water, improving water quality, and regulating runoff. The water balance model was used to calculate water conservation:

$$Q_w = \sum_{i=1}^{n} (P - R - ET) \times A_i \times 10^{-3}, \quad (1)$$

where Q_w is the water conservation (m^3), P is rainfall (mm), R is surface runoff (mm), ET is evapotranspiration (mm), A_i is the area of the ecosystem i (m^2), and i and n are the ecosystem category and quantity, respectively.

Soil conservation is a function of reducing both the erosion capacity of rainwater and soil loss due to ecosystem action. The revised universal soil loss equation (RUSLE) was used to estimate soil conservation:

$$Q_s = \sum_{i=1}^{n} [R \times K \times L \times S \times (1 - C)] \times A_i \times 10^{-4}, \quad (2)$$

where Q_s is soil conservation (t), R is the rainfall erosivity factor ($MJ \cdot mm \cdot hm^{-2} \cdot h^{-1} \cdot a^{-1}$), K is the soil erosivity factor ($t \cdot hm^2 \cdot h \cdot hm^{-2} \cdot MJ^{-1} \cdot mm^{-1}$), L is the slope length factor (dimensionless), S is the slope factor (dimensionless), C is the vegetation cover factor (dimensionless), and A_i is the area of the ecosystem i (m^2).

Carbon fixation and oxygen release occur when ecosystems immobilize carbon in plants and soil to reduce the concentration of carbon dioxide in the air while releasing oxygen through photosynthesis. Carbon fixation and oxygen release were calculated via the carbon sequestration mechanism model:

$$Q_c = \sum_{i=1}^{n} 1.62NPP \times A_i \times 10^{-6} \text{ and} \quad (3)$$

$$Q_o = \sum_{i=1}^{n} 1.2NPP \times A_i, \quad (4)$$

where Q_c is carbon fixation (t), Q_o is oxygen release (t), and NPP is the net primary productivity of vegetation ($gC \cdot m^{-2}$). According to the photosynthesis equation, plants require 1.62 g of CO_2 to produce 1 g of dry matter and release 1.20 g of O_2. Finally, A_i is the area of the ecosystem i (m^2).

Climatic regulation is the effect of ecosystem cooling and humidification through vegetation transpiration and water surface evaporation. We calculated the climate regulation function using the evapotranspiration model:

$$E_{pt} = \sum_{i=1}^{n} EPP_i \times S_i \times D \times \frac{1}{3600r} \text{ and} \quad (5)$$

$$E_{we} = W_a \times E_p \times \gamma \times 10^{-3}, \quad (6)$$

where E_{pt} is the energy consumed by vegetation transpiration ($kW \cdot h$), E_{we} is the energy consumed by the evaporation of water ($kW \cdot h$), EPP_i is the transpiration consumption per unit area of the ecosystem i ($kJ \cdot m^{-2} \cdot d^{-1}$), S_i is the area of the ecosystem i (m^2), D is the number of days with air conditioning use (d), r is the energy efficiency ratio of the air conditioner (value of 3), W_a is the area of wetlands and water (m^2), E_p is the annual evaporation (mm), and γ is the power consumption of the humidifier to convert 1 m^3 of water into steam ($kW \cdot h$, $\gamma = 120$).

Air purification is the absorption and filtration of pollutants in the atmosphere by vegetation, such as SO_2, NO_x, and particulate matter, to reduce the concentration of air pollutants and improve air quality. We used the pollutant purification model to evaluate the air purification function:

$$Q_{ap} = \sum_{i=1}^{n} \sum_{j=1}^{m} Q_{ij} \times A_j \times 10^{-6}, \quad (7)$$

where Q_{ap} is the purification amount of air pollutants (t), Q_{ij} is the unit area purification of class i air pollutants in the class j ecosystem (t·km^{-2}), A_j is the area of the ecosystem j (m^2), i and n are the categories and quantities of the air pollutants, respectively, and j and m are the categories and quantities of the ecosystems, respectively.

Water purification is the adsorption and degradation of water pollutants by the ecosystem. The main pollutants in the water bodies are the chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP). The ecosystem reduces the concentration of COD, TN, and TP, and purifies the water environment. We used the pollutant purification model to evaluate the air purification function:

$$Q_{wp} = \sum_{i=1}^{n} \sum_{j=1}^{m} P_{ij} \times A_j \times 10^{-6}, \quad (8)$$

where Q_{wp} is the purification amount of water pollutants (t) and P_{ij} is the unit area purification of class i water pollutants in a class j ecosystem (t·km^{-2}).

Windbreak and sand fixation reduce wind erosion and sand damage by increasing the soil wind resistance. The revised wind erosion equation (RWEQ) was used to quantify the amount of windbreak and sand fixation:

$$Q_{sf} = \sum_{i=1}^{n} \left[0.1699 \times \left(WF \times EF \times SCF \times K' \right)^{1.3711} \times \left(1 - C^{1.3711} \right) \times A_i \times 10^{-3} \right], \quad (9)$$

where Q_{sf} is the amount of windbreak and sand fixation (t), WF is the climate erosion factor (kg·m^{-1}), EF is the soil erosion factor (dimensionless), SCF is the soil crust factor (dimensionless), K' is the surface roughness factor (dimensionless), and C is the vegetation cover factor (dimensionless).

Flood storage is the ability of an ecosystem to reduce flood damage by regulating storm runoff and reducing flood peaks. Models for reservoir flood control capacity, lake adjustable storage volume, surface water lag, and vegetation regulation and storage were adopted to quantify the storage capacity of reservoirs, lakes, swamps, and vegetation, respectively.

$$C_r = 0.16 C_t, \quad (10)$$

$$C_l = e^{5.653} \times A^{0.680} \times T \times 10^4, \quad (11)$$

$$C_m = 0.3 S \times 10^6, \text{ and} \quad (12)$$

$$C_v = \sum_{i=1}^{n} \left(P - R_{fi} \right) \times A_i \times 10^{-3}, \quad (13)$$

where $C_r, C_l, C_m,$ and C_v are the flood control capacities of the reservoir, lake, swamp, and vegetation, respectively (m^3), C_t is the total reservoir storage capacity (m^3), A is the lake area (km^2), S is the swamp area (km^2), P is the rainstorm rainfall (mm), and R_{fi} is the rainstorm runoff of ecosystem i (mm).

For functional quantity accounting, the water balance model, RUSLE, carbon sequestration mechanism model, and RWEQ were suitable for the calculation of various ecosystem functions. The functional coefficients of the evapotranspiration model, pollutant purification model, and flood and storage model are different in the application of different ecosystem types.

2.2.3. Evaluation Method for Ecosystem Service Values

After measuring the ecosystem service functions, the market value, shadow project, replacement costs, and other methods were used to calculate the various ecosystem service values (Table 1).

Table 1. Evaluation method for ecosystem service value.

Category	Index	Methodology	Description
Ecological product value	Value of agricultural, forestry, animal husbandry, and fishery products	Market value method	Market price of agriculture, forestry, animal husbandry, and fishery, respectively
Ecological regulation service value	Water resources value	Market value method	Market price of water for different purposes
	Water conservation value	Shadow project method	Cost of building the reservoir
	Soil conservation value	Replacement cost method	Cost of dredging the reservoir, and cost of non-point source pollution treatment
	Value of carbon fixation and oxygen release	Reforestation cost method	Cost of afforestation
	Value of climate regulating function	Replacement cost method	Price of domestic electricity
	Value of air purification function	Replacement cost method	Cost of air pollutant control
	Value of water purification function	Replacement cost method	Cost of water pollutant control
	Wind-breaking and sand-fixing value	Replacement cost method	Cost of sand control projects
	Value of flood storage function	Shadow project method	Cost of building the reservoir
Ecological culture service value	Landscape recreation value	Travel cost method	Sum of direct tourist costs and consumer surplus

3. Results

3.1. Accounting for the GEP

The GEP of Hulunbuir City in 2020 was 980.025 billion yuan, showing an increase of 31.94% compared with that in 2015. In the county, the GEP of the forestry and central urban region accounted for 53.90% and 3.13%, respectively, and that of the pastoral and agricultural regions were 257.107 and 163.951 billion yuan, respectively. Compared with that in 2015, the GEP of the forestry, pastoral, agricultural, and central urban regions in 2020 all increased by different amplitudes. The value of the ecological product in Hulunbuir City increased by 8.30% from 46.774 billion yuan in 2015 to 50.657 billion yuan in 2020. Among them, the value of the pastoral and agricultural regions increased by 72.05% and 11.09%, respectively, while the value of the forestry and central urban regions decreased by different amplitudes. Agricultural regions are the main supply areas of ecosystem products, with an output value of 26.476 billion yuan in 2020. The ecological regulation service is the main source of GEP in Hulunbuir City. The value of the ecological regulation service was 852.2 billion yuan in 2020, showing an increase of 219.135 billion yuan compared with that in 2015. The forestry region was the main contributing area for the regulation service. The value of regulation services in the forestry region increased from 332.428 billion yuan in 2015 to 484.054 billion yuan in 2020. The contribution of ecological regulation services in the pastoral region was only inferior to that in the forestry region. The value of regulation services in the agricultural regions in 2020 was 126.874 billion yuan, with an increase of 34.96% compared with the value in 2015. The contribution of regulation services in the central urban regions was the lowest, with a value of 3.851 billion yuan in 2015 and 4.1 billion yuan in 2020. The value of cultural ecosystem services in Hulunbuir City was 77.169 billion yuan in 2020, showing an increase of 22.64% compared with the value in 2015. The value of culture ecosystem services in the central urban region was only lower than that of the forestry region, yielding a value of 24.722 billion yuan in 2020 (Table 2).

Table 2. Accounting results of GEP on each region in 2015 and 2020 (100 million·a^{-1}).

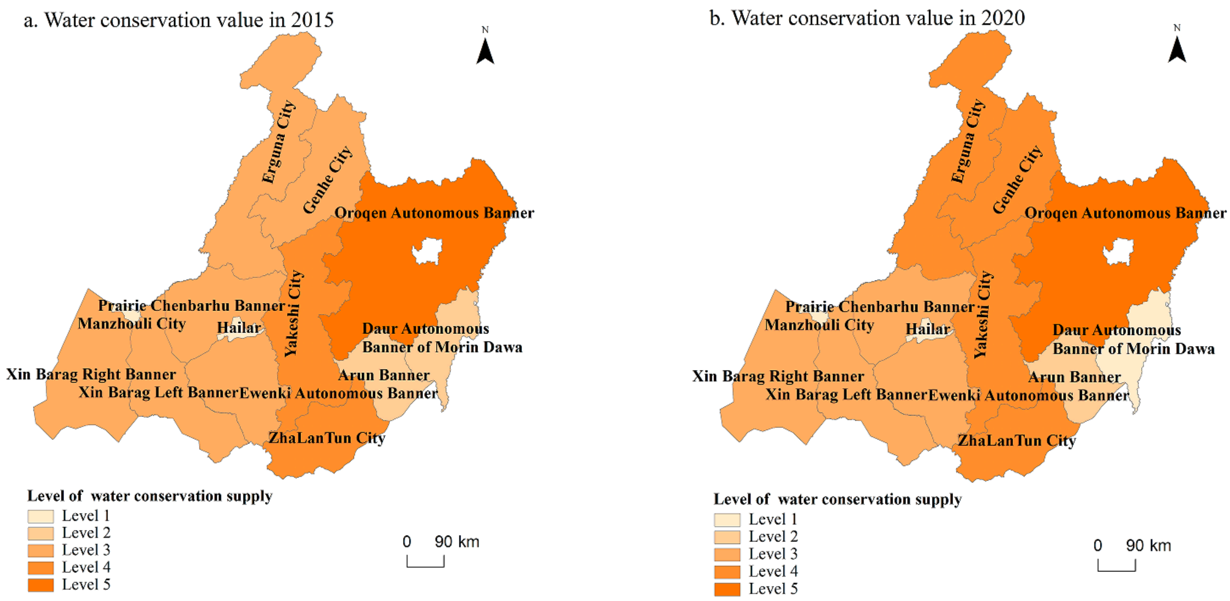
Region	Year	Ecological Product Service Value	Ecological Regulation Service Value	Ecological Culture Service Value	GEP
Forestry region	2015	146.68	3324.28	230.38	3701.34
	2020	122.48	4840.54	319.66	5282.68
Pastoral region	2015	58.44	2027.74	72.18	2158.36
	2020	100.55	2371.72	98.79	2571.07
Agricultural region	2015	238.32	940.12	90.70	1269.13
	2020	264.76	1268.74	106.02	1639.51
Central urban region	2015	24.29	38.51	235.93	298.74
	2020	18.77	41.00	247.22	306.99

Among the three ecological service values, the main service function of the forestry, pastoral, and agricultural regions was the regulation service, and the main function of the central urban region was the culture ecosystem service. The cultural service function was the second largest function in the forestry region, with an increasing proportion. Recently, the forestry region has explored the cultural attributes of ecological products and continued to create high-grade ecological tourism. Compared with 2015, the number of tourists in pastoral regions increased in 2020, resulting in an increase in the proportion of the cultural service value. However, this also yields problems and hidden dangers to the ecological environment of pastoral regions. For example, the destruction of grasslands is common. The proportion of the ecological regulation service value in pastoral regions slightly decreased. After returning farmland to grassland, the proportion of the product value provided by pastoral regions has considerably increased according to the balance of grass storage. Services provided by ecological products are the second largest function in agricultural regions, but the proportion of ecological products decreased in 2020. The proportion of regulation services in agricultural regions increased, indicating that the return of farmland to forest and grassland has been effective. The second major function of the central urban region is to regulate services. Government offices in the central urban region attach importance to ecological environmental protection, increases in afforestation efforts, and improvements in vegetation coverage. The proportion of the ecological regulation service value in the central urban region has increased compared with that in 2015 (Table 2).

3.2. Calculation of Ecological Regulation Services Value

According to the above analysis, the ecological regulation service is the main value source of GEP in Hulunbuir City. The value of the eight types of regulation services in the 13 counties and districts of Hulunbuir City was classified by the natural break point method, and distribution maps of the eight types of regulation services in 2015 and 2020 were obtained (Figure 2). Oroqen is the main supply area of water conservation. The level of the water conservation supply area in Erguna and Genhe increased from third in 2015 to fourth in 2020, mainly due to the significant increase in the shrubby land area. As the ecosystem area in Morin Banner decreased by 15.01% in 2020 compared with that in 2015, the water conservation supply grade of Morin Banner decreased to the first level (Figure 2a,b). The rainfall erosivity of Oroqen in 2020 was weakening, but the vegetation coverage of Oroqen decreased, resulting in a reduction in the soil conservation grade in 2020. The rainfall erosivity of Erguna, Genhe, Yakeshi, Zhalantun, Ewenki, Arun Banner, and Morin Banner increased in 2020, but the vegetation coverage and ecosystem area increased, and there was an increase in the overall soil conservation grade. Higher vegetation coverage can hinder rainfall, with a reduction in the actual soil erosion (Figure 2c,d). Carbon fixation and oxygen release are the main functions of ecological regulation services in Hulunbuir City, and their value accounted for more than 30% of the regulation services. Oroqen is the highest-grade supply area for carbon fixation and oxygen release. The functional levels of carbon fixation and oxygen release in Genhe, Chen Banner, Xin Left Banner, Xin Right

Banner, and Morin Banner decreased in 2020, mainly due to the decrease in the ecosystem area (Figure 2e,f). The value of climate regulation accounted for more than 40% of the value of ecological regulation services in Hulunbuir City. The level of the supply area for the climate regulation function changed negligibly between 2015 and 2020. The service function of climate regulation is composed of two parts: vegetation transpiration and water surface evapotranspiration. Areas with high vegetation coverage and a large water area are the main functional areas for climate regulation. The forest area of Oroqen and Yakeshi ranked first and second in Hulunbuir City, respectively; therefore, the service level of climate regulation in these two regions was high. Most of Hulun Lake is located in the Xin Right Banner, which is also in the top tier of the climate regulation value (Figure 2g,h). As forests have the strongest ability to remove SO_2, NOx, and particulate matter from air pollutants, Oroqen, with the largest forest area, has the strongest ability to remove air pollutants. Yakeshi, Erguna, and Genhe are in a Level 4 supply zone. Grasslands can also purify SO_2, NOx, and particulate matter. The air purification of Chen Banner, Xin Left Banner, Xin Right Banner, Ewenki, and Zhalantun was in the three-level supply area. The air purification level in Morin Banner was downgraded from Level 2 to 1, mainly due to a 15.20% reduction in the ecosystem area (woodland, shrubland, and grassland) in 2020 compared with that in 2015 (Figure 2i,j). Wetlands and water bodies are the main ecological areas for water quality purification. Xin Left Banner and Xin Right Banner have large areas of wetlands and water bodies, such that they are the main functional areas for water quality purification. In 2020, the wetland area in Hailar and Manzhouli decreased by 17.97% and 35.35%, respectively, compared with that in 2015, such that the grade of the water purification supply area decreased from Level 2 to 1 (Figure 2k,l). Changes in the windbreak and sand fixation functions were mainly related to regional meteorological and vegetation factors. Xin Left Banner and Xin Right Banner were the main functional areas for windbreak and sand fixation. The windbreak and sand fixation capacity of Oroqen and Genhe increased by 61.65% and 46.43%, respectively, in 2020, with additional improvements to the functional grade (Figure 2m,n). The grade of the flood storage function supply area in Hulunbuir City changed negligibly between 2015 and 2020. The flood storage function is mainly related to the storage capacity of reservoirs, lakes, marshes, and vegetation. Erguna, Genhe, Xin Left Banner, Ewenki, and Xin Right Banner have high comprehensive flood storage capacities and are the main supply areas for flood storage.



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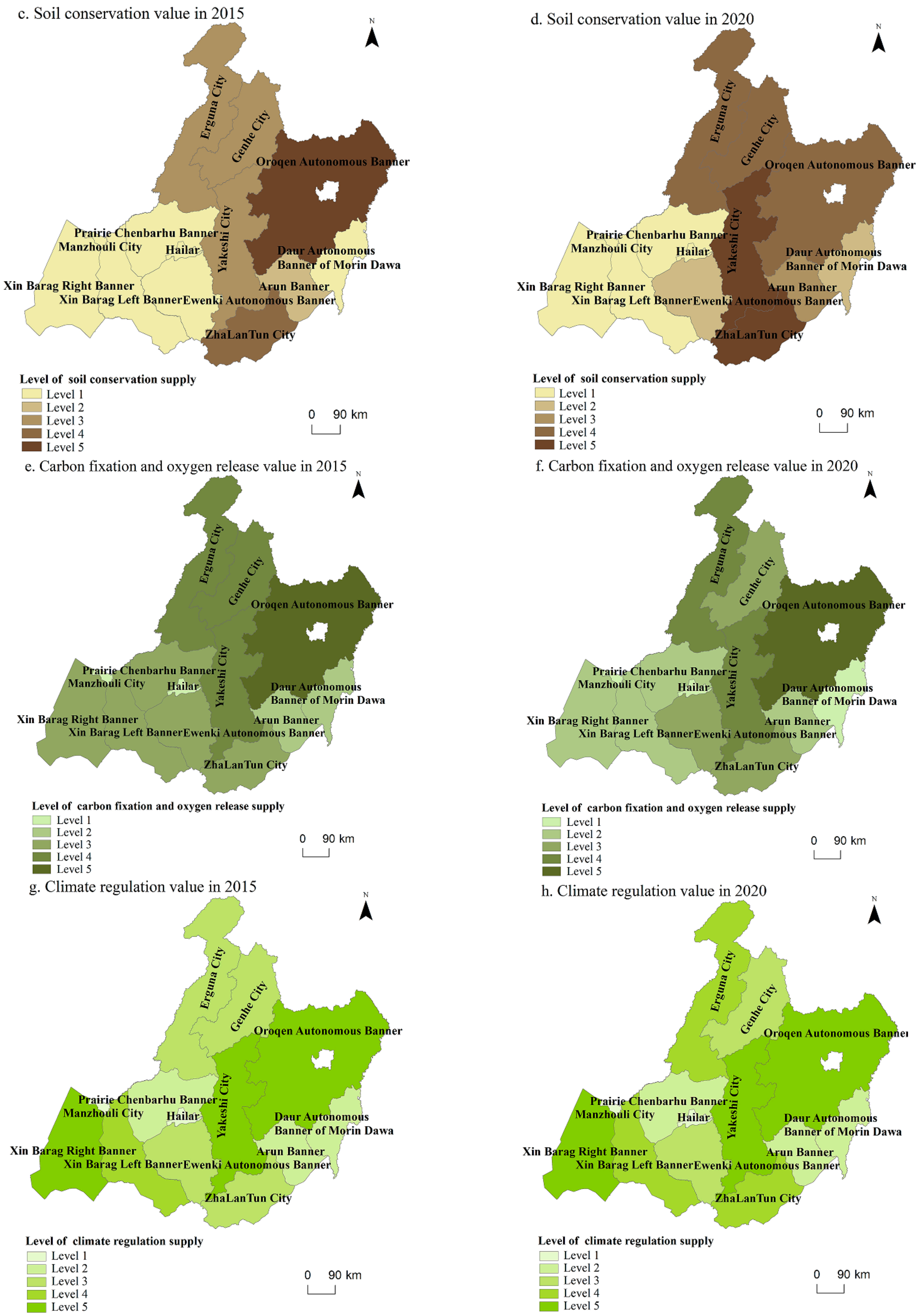

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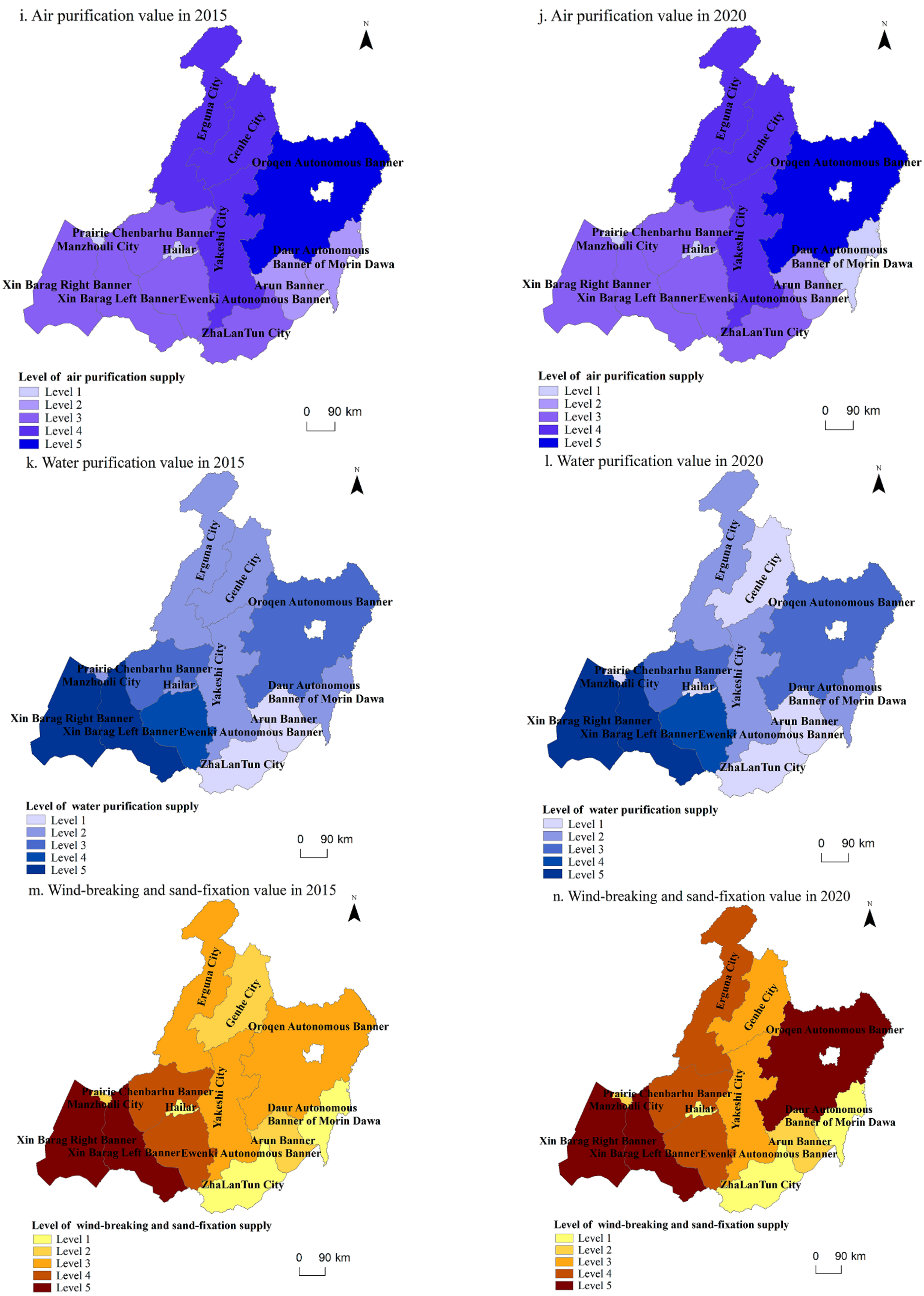

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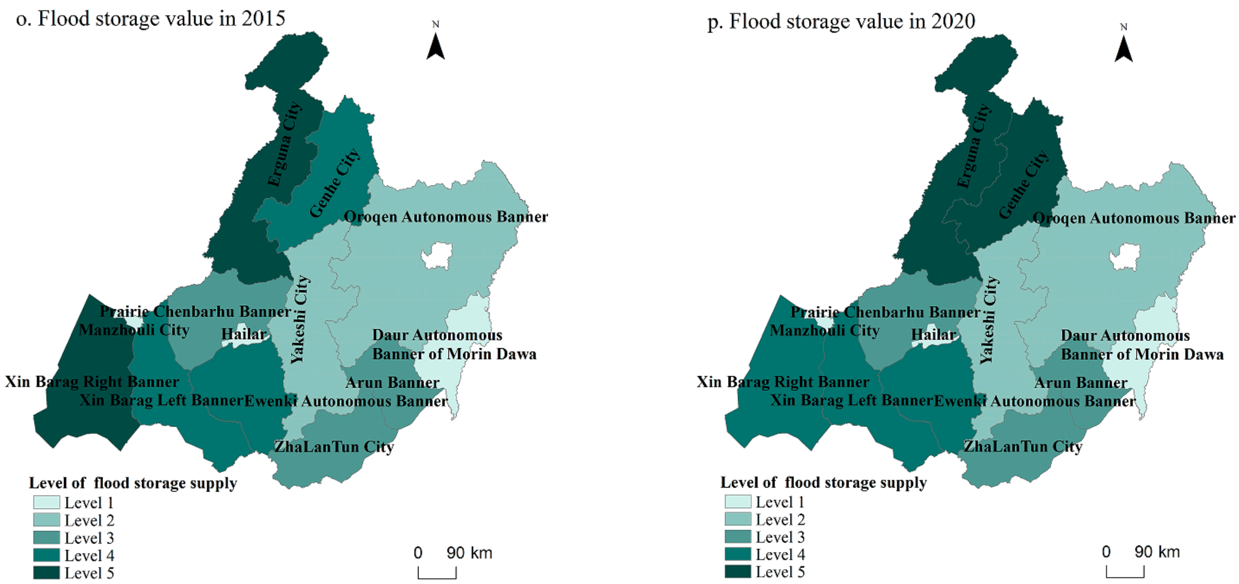

Figure 2. Spatial distribution map of eight regulatory function grades.

3.3. GEP Assessment in Major Ecological Lands

Overall, the forest ecosystem of Hulunbuir City created the highest value. The GEP of the forest ecosystem accounted for 62.32% in 2020, showing an increase of 180.535 billion yuan compared with that in 2015, owing to construction results from key forestry projects, such as the implementation of the natural forest protection project, returning farmland to forest, forest tending, and closing mountains for forest cultivation. During the implementation of the natural forest protection project, the forest resources management and protection system was implemented, which reduced the consumption of forest resources and realized the growth of both forest area and forest stock. Forest ecosystem services have been enhanced, and the capacity of carbon sinks has been improved. Through the implementation of returning farmland to forest, the forest coverage rate of Hulunbuir City has increased by 0.5%, and the ecological environment has been significantly improved. Forest-tending projects improve the growth environment of trees and increase the survival rate of seedlings. Forest closure is a traditional forest cultivation method in China, which clearly affects soil and water conservation, increases species diversity, and reduces forest diseases and pests. The vast grassland ecosystem area played an important role in Hulunbuir City in 2015, accounting for 25.72% of the GEP. Unfortunately, the role of grassland ecosystems gradually declined in 2020, mainly due to the inappropriate reclamation of grassland via human activity, predatory exploitation, overgrazing, and other behaviors, resulting in an increasing reduction in the grassland area, serious degradation, and even desertification. Hulunbuir City has diverse wetland types and is an important ecological region in the cold and arid regions of northern China. The ecological value of wetlands accounted for 4.77% in 2020, which was 0.69% lower than that in 2015. Natural factors, such as insufficient water sources, and human factors, such as agricultural reclamation, grazing, and mowing of wetland vegetation, contributed to wetland ecosystem disturbances. Hulunbuir City has more than 3000 rivers and more than 500 lakes. Water ecosystem services are equally important. The GEP of the water ecosystem accounted for 7.69% and 6.73% in 2015 and 2020, respectively. The most important sources of forest, grassland, wetland, water, and farmland value were found to be Oroqen, Xin Right Banner, Xin Left Banner, Xin Right Banner, and Morin Banner, respectively. The value of the forest ecosystem was mainly reflected in five aspects: climate regulation, carbon sequestration and oxygen release, water conservation, flood storage, and forest tourism. The grassland ecosystem value was mainly concentrated in five categories: carbon sequestration and oxygen release, climate regulation, water conservation, livestock product supply, and grassland tourism. Categories with a high contribution to the wetland ecosystem value were flood storage, wetland tourism, climate regulation, carbon sequestration, and oxygen release. The value of the water ecosystem was mainly derived from five categories: climate regulation, water tourism, flood storage, water resources supply, and fishery product supply (Table 3).

Table 3. Contribution rate of ecosystem functional services value of LUCC.

Ecosystem	Products Value	Water Resources	Water Conservation	Soil Conservation	Carbon Fixation and Oxygen Release	Climate Regulating	Air Purification	Water Purification	Wind-Breaking and Sand-Fixing	Flood Storage	Landscape Recreation
Forest	0.44%		14.41%	0.62%	32.67%	38.38%	0.19%		0.01%	7.40%	5.89%
Grassland	8.95%		15.91%	0.27%	37.64%	29.36%	0.21%		0.04%	2.42%	5.20%
Wetland			0.80%	0.01%	1.87%	28.46%		0.21%		39.23%	29.43%
Water	1.52%	2.91%				61.92%				10.37%	23.28%

Figure 3 shows the proportion of the ecosystem value composition in each region. The forestry region not only has a large area of forest, but also Heishantou grassland, Erguna wetland, Genhe wetland, and other important ecosystems. Therefore, the values of grassland and wetland in the forestry region were 8.97% and 2.86%, respectively. The pastoral region not only has a vast grassland, but also contains Honghuerji forest, Hulun Lake, Bier Lake, Huihe wetland, and other important functional areas of the ecosystem. Therefore, the proportions of the forest and water values in the pastoral region were 15.94% and 12.86%, respectively. The Chaihe National Forest Park, Yaru River, and Nierji Reservoir were observed to be important ecological functional areas as agricultural regions. The values of forests, grasslands, farmland, water bodies, and wetlands in the agricultural region were 58.41%, 15.90%, 12.26%, 9.61%, and 3.83%, respectively. The proportion of forest value in Hailar district was the highest, followed by the grassland, water, and farmland values. The water ecosystem of Manzhouli played the greatest role, mainly because part of Hulun Lake is located in Manzhouli. The wetland value of Manzhouli was relatively high where the Erka wetland is located.

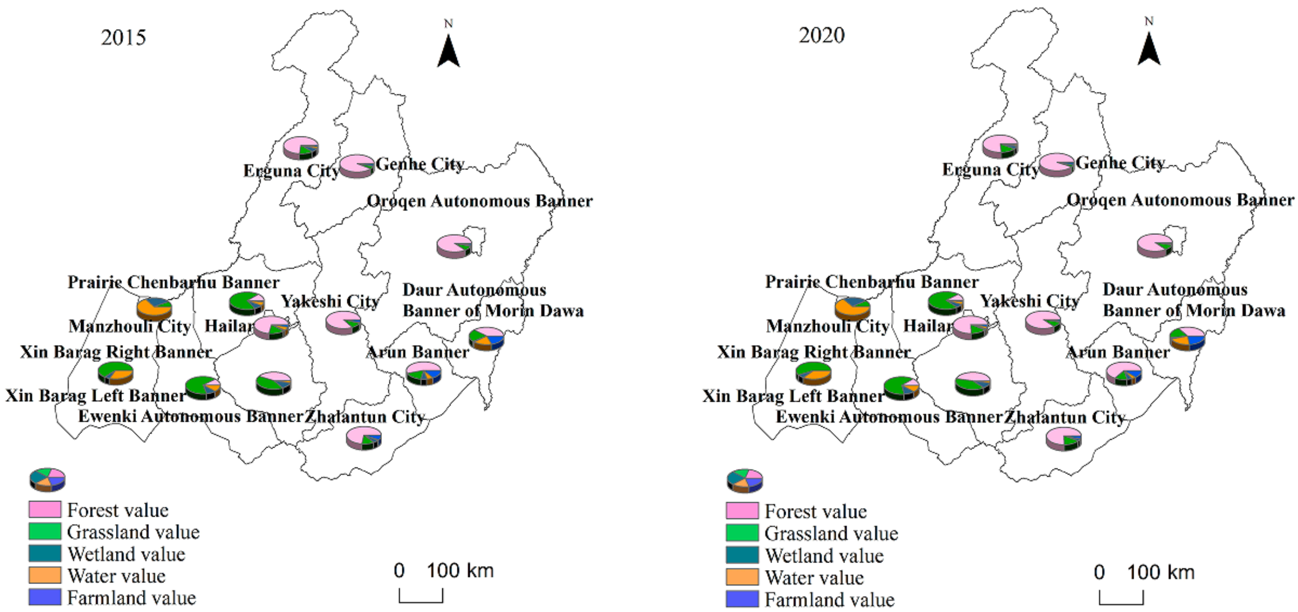

Figure 3. Proportion composition of ecological-type values of each region in 2015 and 2020.

3.4. GEP Application

The GEP per unit area can reflect the ecosystem supply capacity. A higher GEP per unit area indicates a stronger ecosystem supply capacity in the region. The GEP per unit area of Hulunbuir City in 2020 was 3.7736 million yuan, showing an increase of 31.94% compared with 2015, indicating that the overall ecosystem supply capacity of Hulunbuir City has been greatly improved. Compared with Hulunbuir City, Manzhouli, Hailar, Zhalantun, Genhe, Erguna, and Yakeshi have greater ecosystem supply potentials, while other regions have lower supply capacities. The GEP per capita refers to the GEP enjoyed by each person. The GEP per capita could reflect people's ecological welfare level, with a higher value indicating more ecological welfare everyone enjoys. The GEP per capita of Hulunbuir City in 2020 was 438,200 yuan, with an increase of 40.79% compared with 2015, indicating that the per capita ecological well-being level of Hulunbuir City has significantly increased. Compared with Hulunbuir City, people in Xin Right Banner, Erguna, Xin Left Banner, Genhe, Oroqen, Chen Banner, and Arun Banner enjoy more ecological welfare per capita, while the level of ecological well-being per capita in other regions is low. The GGI can reflect the quantitative relationship between the "Two Mountains." The GGI of Hulunbuir City in 2020 was 8.36, which was considerably higher than the national average of 1.01, indicating that the resource value of "clear waters and green mountains" in Hulunbuir City was considerably greater than that of "gold and silver mountains." There was significant potential for ecological factors to be transformed into production factors, and ecological wealth to be transformed into material wealth. Compared with those in 2015, the growth rates of the GEP, GDP, and GGI of Hulunbuir City in 2020 were 31.94%, 20.84%, and 9.18%, respectively, showing that the ecological protection of Hulunbuir City has achieved success. The regional economy has sustained development, and the ability to transform "clear waters and green mountains" into "gold and silver mountains" is also improving. Additionally, ecological protection achievements have far exceeded the level of economic growth, laying a solid foundation for the ecological status of Hulunbuir City, but we must also continue to explore the green-economic development model. Comparing the GGI of each county in Hulunbuir City, we found that in 2015 and 2020, the GGI values of Erguna, Genhe, Oroqen, Xin Left Banner, Xin Right Banner, and Yakeshi were higher than the overall level of Hulunbuir City, indicating that these six regions effectively use ecological advantages to develop the regional economy, while those of the other regions were lower than the overall level of Hulunbuir City over the five years. GGI levels at Hailar and Manzhouli were lower than the national average. By comparing the GGI growth rate of each county in Hulunbuir City, we can conclude that the GGI growth rate of Erguna, Genhe, and Zhalantun was higher than the overall GGI growth rate of Hulunbuir City, indicating that the transformation of the "Two Mountains" in these three regions has achieved remarkable results. The GGI growth rate of Yakeshi, Arun Banner, Chen Banner, Oroqen, and Morin Banner was lower than the overall GGI growth rate of Hulunbuir City. The "Two Mountains" in these regions have a large transformation space; therefore, they must fully rely on advantageous ecological resources to transform them into economic development power. The transformation capacity of the "Two Mountains" in Hailar, Manzhouli, Xin Right Banner, Ewenki, and Xin Left Banner was decreasing, indicating that we must further promote the ecological article based on the traditional economic model (Figure 4).

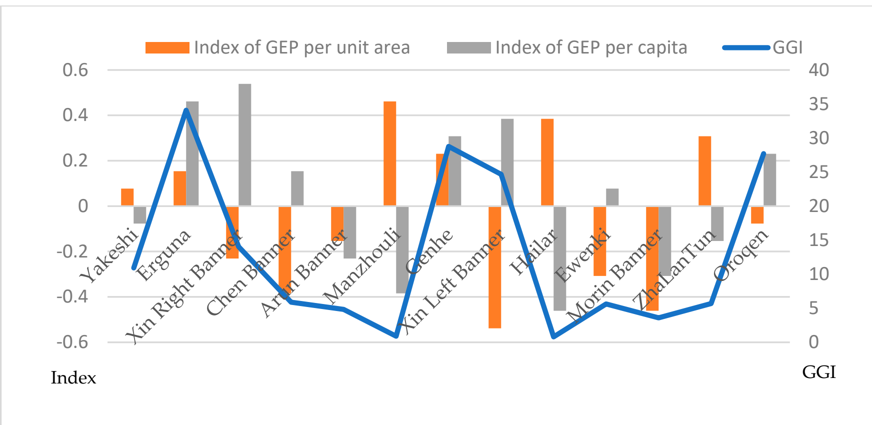

Figure 4. The index of GEP per unit area, index of GEP per capita, and GGI of each region in 2020.

3.5. Transformation Path of "Two Mountains"

According to the above analysis, we explored the transformation path of the "Two Mountains" in each county of Hulunbuir City. Considering the ecosystems and industrial types of counties included in the four ecological economic zones, and that the transformation paths of the "Two Mountains" are replicable and transferable, this study selected the four ecological economies of forestry, pastoral, agricultural, and central urban regions as the entry point of analysis.

3.5.1. Transformation Path of "Two Mountains" in the Forestry Region

The forestry region is the main contribution area of regulation service, with a regulation service value accounting for 91.63% of the GEP and a growth rate of 45.62%, ranking first among the four ecological economic zones. Therefore, the regulation service is the key point of "Two Mountains" transformation in the forestry region. The eight main types of regulation services of the forestry region were water conservation, soil conservation, carbon fixation, oxygen release, climate regulation, air purification, windbreak, and sand fixation. Among them, carbon fixation and oxygen release function were the most prominent, with a value of up to 180 billion yuan. The forestry region can directly realize the transformation of the carbon sequestration and oxygen release values for the "Two Mountains" through carbon sink trading. The transformation of other regulatory values can also be indirectly completed through the ecological compensation mechanism, i.e., the principle of "who uses, who pays." There was a significant correlation between the increase in the ecosystem regulation service value and the increase in vegetation coverage. The vegetation coverage of the forestry region was 84.41% in 2020. Therefore, the forestry region should continue to implement various ecological protection construction projects and transform the ecological value of the regulation service into economic value. The second major function of forestry regions is to provide cultural services, which accounted for 6.05%, and the growth rate is the first among the four ecological economic zones, indicating that the ecological cultural function of the forestry region has great potential. The main natural resources in the forestry region are forests and wetlands. The forestry region continues to explore the cultural elements of forest and wetland tourism while building a well-known forest and wetland tourism destination and transforming forest and wetland ecosystem value into tourism economic value. The ecological products value in the forestry region accounted for 2.32% in 2020, which decreased by 16.49% compared with 2015, indicating that the ecological products value needs to be further explored. Forestry regions should focus on brand agriculture and realize the circular transformation of the "Two Mountains." The GGI of the forestry region is 25.37, which is much higher than the average of Hulunbuir City (8.36), indicating that the ecological level of the forestry region is much higher than the economic level. The focus of the "Two Mountains" transformation in the forestry region is the rapid transformation from GEP to GDP.

3.5.2. Transformation Path of "Two Mountains" in the Pastoral Region

The ecological regulation services value in the pastoral region accounts for 92.25% of GEP, with a growth rate of 16.96%. Therefore, regulation services are also the focus of "Two Mountains" transformation in the pastoral region. The area of grassland, wetland, and water bodies in the pastoral region is large. Among the eight regulation services, climate regulation, water purification, windbreak, sand fixation, and flood storage are the main ecological functions in the pastoral region. The ecological regulation value should be transformed into economic value via ecological compensation. Grassland is an ecosystem with both ecological and production functions. The grassland ecosystem not only has important ecological functions, but also provides pasture resources for livestock to maintain metabolism. The ecological products supply value in the pastoral region accounted for 3.91%. The growth rate was 72.05%, which was much higher than that of other ecological economic zones, indicating that the supply function of ecological products in the pastoral region had great potential. We must, therefore, extend the industrial chain of pastoral products, enhance the brand value of livestock products, and transform the ecological products value of the pastoral region into economic value. The cultural ecosystem services value in the pastoral region accounted for 3.84% of the GEP, with a growth rate of 36.87%, which was slightly lower than that of the forestry region, indicating that the cultural ecosystem services value of the pastoral region had greater potential. Pastoral regions should integrate the development of grassland tourism with cultural understudies, actively promote "driving + experience" grassland tourism, conduct a series of grassland cultural activities, and create high-end grassland tourism destinations, to improve the ecotourism value of pastoral regions. The GGI of the pastoral region was 12.55, which was slightly higher than the average of Hulunbuir City, indicating that the ecological surplus of the pastoral region was slight. The focus of the transformation of "Two Mountains" in the pastoral region was to promote the transformation from GEP to GDP while maintaining ecological balance.

3.5.3. Transformation Path of "Two Mountains" in the Agricultural Region

The ecological regulation service value in the agricultural region accounts for 77.38% of GEP. Therefore, the regulation service is also the focus of "Two Mountains" transformation in the agricultural region. The growth rate was 34.96%, indicating that the ecosystem regulation function in the agricultural region has been greatly improved through ecological construction projects, such as returning farmland to forest and grassland. The ecological products supply service is the second largest function of the agricultural region, accounting for 16.15%, which is the highest in the four ecological economic zones. The growth rate was 11.09%, indicating that the product supply function in the agricultural region continued to strengthen. It is necessary to continue to develop and innovate green and low-pollution ecological agricultural products and enhance the brand value of geographical indication agricultural products. The value of agricultural products can be directly transformed into industrial economic value. The cultural ecosystem services value in the agricultural region accounted for 6.47% of GEP, with a growth rate of 16.89%, indicating that the cultural ecosystem services in the agricultural region need to be explored further. We will deepen the integration of culture and tourism in the agricultural region. The ecological cultural value of the agricultural area is transformed into tourism economic value by conducting agricultural expo activities. The GGI of the agricultural region is 4.70, which is lower than the average of Hulunbuir City, indicating that the ecological level of the agricultural region is lower than the economic level. The focus of "Two Mountains" transformation is the two-way transformation of GEP and GDP.

3.5.4. Transformation Path of "Two Mountains" in the Central Urban Region

The main function of the central urban region was the culture ecosystem service. The culture ecosystem service value in the central urban region accounts for 80.53% of GEP, with a growth rate of 4.79%. The transformation of the ecotourism value is the focus of the transformation of the "Two Mountains" in the central urban regions. As the main collection and distribution center of tourists in Hulunbuir City, the central urban regions have many tourists, but negligible ecotourism resources. By adding ecological resources and cultural elements and performing research and other measures of ecological cultural activities, tourists will be attracted to the ecotourism products of the region. The proportion of the central urban regulation service was 13.36%. The regulation function of Hailar mainly comes from urban greening and Xishan National Park, while the regulation service of Manzhouli mainly focuses on urban greening and Hulun Lake. Therefore, attention should be paid to the ecological protection of Xishan National Park and Hulun Lake. The proportion of the ecological products supply service in the central urban region is 6.11%, which is 22.75% lower than that in 2015, indicating that the value of ecological products in the central urban region needs to be further explored. The GGI of the central urban region is 0.84, which is far lower than the average of Hulunbuir City, indicating that the ecological level of the central urban region is far lower than the economic level. The focus of the transformation of "Two Mountains" in the central urban region is the transformation of GDP into GEP, and then GEP into GDP.

4. Discussion

4.1. Differences in GEP Results

Evaluation methods, selection of evaluation indicators, and price parameters will all impact GEP results. If different accounting methods and indexing systems are selected for the same region regarding different price parameters, the calculated amount of ecosystem functions and values will vary. Regarding similar ecological niche areas of relevant research results combined with the practical situation of the ecological resources of Hulunbuir City, this study determined the index for 11 types of accounting. Accounting methods focus on references to the 2022 "GEP Accounting Specification (Trial)" issued by the National Development and Reform Commission of China. The price is widely used in the practical life parameters and some references. After comparing the calculated research results with the results of a previously published study on calculating the GEP for the Inner Mongolia Autonomous Region [41], a report on the first comprehensive evaluation of forest ecosystem service value in Hulunbuir City [42], and the National County/Municipal District Gross Ecosystem Product (GEP) Research Report 2021 [43], we can conclude that the evaluation results of this study were within a reasonable range.

4.2. Research Limitations and Prospects

Owing to the impact of the COVID-19 pandemic, Hulunbuir City tourism data in 2020 cannot reflect the real values of regional cultural services. This study selected tourism data from 2019 to calculate the values for recreational cultural services in 2020. Due to difficulties in data acquisition, the functional value of pest and disease control was not accounted for. There are inevitable errors in the acquisition and processing of remote sensing data, meteorological data, soil data, and other data. Although there were some errors in the research results, this study accurately reflects the state and changes in the ecological environment of each county in Hulunbuir City during the 12th and 13th Five-Year plans. It also provides a scientific basis for future policy formulation with respect to ecological protection and construction in each region. In a future study, the GEP accounting of Hulunbuir City will be calculated every five years as a normalization work. The next study is to calculate the GEP of 12 cities in Inner Mongolia and verify the importance of Hulunbuir City's ecological status through the calculation results. It is important to promote the further development of ecological civilization construction in Inner Mongolia.

5. Conclusions

We selected 2015 and 2020 as the research nodes to compare and analyze the characteristics of GEP in 13 counties. We verified the value status of "clear waters and green mountains" in the study area to explore the effects of ecological protection in the 12th and 13th Five-Year plans of Hulunbuir City. Based on the results of the two stages, we explored the transformation path of the "Two Mountains" value in 13 counties. The main conclusions were as follows.

The GEP of Hulunbuir City in 2020 was 980.025 billion yuan, of which the product value was 50.657 billion yuan, the regulation service value was 852.2 billion yuan, and the cultural service value was 77.169 billion yuan. The GEP ranking for the counties in Hulunbuir City was as follows: forestry region > pastoral region > agricultural region > central urban region. The agricultural region was the main supply area of ecosystem products, the forestry and pastoral regions were the main contribution areas of regulating services, and the value of cultural ecosystem services in the central urban region was second only to the forestry region. Oroqen is the main supply area for water conservation. The soil conservation capacity improved in Erguna, Genhe, Yakeshi, Zhalantun, Ewenki, Arun Banner, and Morin Banner. Carbon fixation and oxygen release were the main functions of the ecological regulation service in Hulunbuir City. Oroqen had the highest carbon fixation and oxygen release capacity. Climate regulation was the most important ecological regulation function of Hulunbuir City. Oroqen, Yakeshi, and Xin Right Banner were the main source areas for the climate regulation value. Oroqen had the strongest air purification capacity. Xin Left Banner and Xin Right Banner were the main areas of the water purification function, as well as of wind-breaking and sand-fixing. The flood regulation and storage capacity of Erguna, Genhe, Xin Left Banner, Ewenki, and Xin Right Banner were high. The GEP of major ecological lands was in the order of forest > grassland > water body > wetland > cropland. By region, the order of the ecosystem value is forest, grassland, wetland, farmland, and water bodies in forestry regions. The ecosystem value in pastoral regions was ranked as follows: grassland, forest, water body, wetland, and farmland. The order of the ecosystem value in agricultural regions is forest, grassland, farmland, water body, and wetland. The order of the ecosystem value in Hailar is forest, grassland, water body, and farmland. The order of the ecosystem value in Manzhouli is water body, wetland, grassland, forest, and farmland. The GGI of Hulunbuir City in 2020 was 8.36. The GEP per unit area and GEP per capita in the forestry region were high, and the GGI was much higher than 8.36. The GEP per unit area of the pastoral region was low, while the GEP per capita and the GGI were high. The GEP per unit area and GEP per capita in the agricultural region were low, and the GGI was slightly lower than 8.36. The GEP per unit area in the central urban region was high, while the GEP per capita was low, and the GGI was much lower than 8.36. The growth rate of GGI was high in Erguna, Genhe, and Zhalantun, somewhat low in Yakeshi, Arun Banner, Chen Banner, Oroqen, and Morin Banner, and exhibited a downward trend in Hailar, Manzhouli, Xin Right Banner, Ewenki, and Xin Left Banner.

In this study, the GEP was calculated on the county scale and applied to the transformation practice of the "Two Mountains." These research ideas and methods can be extended to similar regions in China and around the world, with considerable application value and social significance. Firstly, through comparative evaluation of GEP among counties, more targeted ecological protection measures can be implemented, and ultimately the overall ecological protection of cities and counties can be improved. Secondly, GEP was calculated in accordance with the accounting methods in the specification issued by the national authority in 2022, so that the accounting results can be traced, verified, and comparable. For the 13 counties included in this study, the accounting results were determined to be comparable, which is an innovation of this study. Thirdly, we promoted the transformation of GEP from an "accounting value" to a "policy point." The transformation path of "Two Mountains" in the forestry and pastoral regions can be extended to the counties with good ecological environments and poor economies. The transformation path of "Two Mountains" in the agricultural region can be extended to the counties with poor ecological environments and economies. The transformation path of "Two Mountains" in the central urban region is suitable for areas with developed economies and poor ecological environments. In future research, the GEP accounting scope should be expanded to calculate the GEP of all counties in Inner Mongolia and throughout China. The accounting results are applied to the transformation practice of "Two Mountains" to actively promote the construction of ecological civilization at the county scale.

Author Contributions: Conceptualization: N.Z. and H.W.; methodology: N.Z. and J.Z.; software: N.Z. and Y.B.; validation: N.Z., H.W., J.Z., Y.B. and S.Y.; formal analysis: N.Z. and H.W.; investigation: N.Z. and S.Y.; resources: N.Z. and Y.B.; data curation: N.Z. and S.Y.; writing—original draft preparation: N.Z., H.W., J.Z., Y.B. and S.Y.; writing—review and editing: N.Z., H.W., J.Z., Y.B. and S.Y.; visualization: N.Z. and J.Z.; supervision: H.W.; project administration: N.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Hulunbuir Federation of Social Sciences, China (HSK202211) and the Inner Mongolia University Science and Technology Research Project, China (NJSY22298).

Data Availability Statement: The data used in this study are from the Remote Sensing Institute of the Chinese Academy of Sciences (https://data.casearth.cn/sdo/detail/5fbc7904819aec1ea2dd7061 (accessed on 2 June 2022)), the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (https://www.resdc.cn/ (accessed on 7 June 2022)), the Global Land Data Assimilation System (http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings (accessed on 17 June 2022)), the National Tibetan Plateau/Third Pole Environment Data Center (https://disc.gsfc.nasa.gov/datasets/GLDAS_CLSM025_DA1_D_2.2/summary?keywords=runoff (accessed on 22 June 2022)), and the National Aeronautics and Space Administration (http://www.nasa.gov/ (accessed on 2 July 2022)).

Acknowledgments: The authors thank the Hulunbuir Bureau of Statistics in China for technical and data support.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study, the collection, analyses, or interpretation of data, the writing of the manuscript, or the decision to publish the results.

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