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Study on the Measures for Optimizing China's Provincial Territorial Space Based on the Perspective of Resource and Environmental Carrying Capacity in the New Situation

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Abstract: The comprehensive resource and environment carrying capacity (RECC) evaluation is an important method for measuring the rationality of the population, resource, and environment allocation, which is an important scientific guidance for scientific research and the judgment of regional economic and social development potential and the optimization of the national land spatial pattern. This paper constructs a comprehensive evaluation index system of the RECC under the new situation of climate policy and high-quality economic development; it analyzes the factors influencing the RECC, the overall level, the spatial difference, and the carrying status by using the TOPSIS model based on the entropy weight method, and it identifies the shortcomings; then, it analyzes the characteristics of regional dynamic change and sustainable development trend, and finally, it simulates the optimal spatial pattern under the scenario simulated by the FLUS model. The conclusions are as follows: ① the resource factors have the greatest influence on the carrying capacity of the resources and the environment, followed by economic factors. Among them, per capita water resources, forest coverage rate, and health institutions have the highest impact on RECC. ② The overall level of comprehensive RECC from 2015 to 2020 shows an upward trend, and although the positive impact of resource-led provinces on the level of economic development power and RECC is greater than the negative one, the environmental support is the shortcoming of the future development of the regional economy. ③ The overall spatial performance of RECC is characterized as being high in Guanzhong, second in northern Shaanxi, and low in southern Shaanxi. The northern area of Yulin in the Guanzhong Plain City Cluster, which is an important national energy chemical base, is the core of the national-level urbanization development areas, and the northern area of the Guanzhong Plain City Cluster is the key choice of the provincial-level urbanization development areas. The area along the west bank of the Yellow River in the Qinba Mountain area in southern Shaanxi and the Baiyu Mountain area in northern Shaanxi can be positioned as national key ecological function areas.

Keywords: RECC; provincial territorial space; entropy weight TOPSIS model; Shaanxi

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1. Introduction

Resources and the environment are the core themes of sustainable development research, and comprehensive RECC evaluation is an important method to measure the reasonableness of population, resource, and environmental allocation, which has important scientific guidance significance for scientific research and the judgment of regional economic and social development potential and the optimization of territorial spatial patterns [1]. With the uneven development of the regional economy and society, human society is facing the severe situation of tightening resource constraints, serious environmental pollution, and ecosystem degradation [2]. China, as the world's largest developing country, has gradually shifted from an over-reliance on the crude development mode of high resource consumption and high pollution emissions to the formation of a low-consumption, high-quality conservation, and intensive development mode, with the construction of an ecological civilization as the core [3]. This is particularly the case since 22 September 2020 when China proposed at the 75th session of the United Nations General Assembly that “carbon dioxide emissions strive to peak by 2030, and strive to achieve carbon neutrality by 2060”, which means the decoupling of China’s economic and social development from carbon dioxide emissions; China’s coal-based energy structure, industrial structure, transportation structure, and land use structure are facing the important change. These factors, coupled with the normalization of COVID-19 prevention and control as well as the socioeconomic impact brought by the high-quality economic development, all put forward new requirements for China’s development. China’s top-level design document for achieving peak carbon and carbon neutrality goals, “the CPC Central Committee and the State Council on the complete and accurate implementation of the new development concept of carbon peaks and carbon neutrality work”, clearly states that “the carbon peaks and carbon neutrality goals will be fully integrated into the medium and long-term planning of economic and social development, and strengthen the support of national development planning and territorial spatial planning“ [4]. As carbon dioxide is not defined as an atmospheric pollutant in China, it is not considered as a greenhouse gas in the existing national planning and related studies, and at the same time, the economic growth rate is slowing down under the trend of the high-quality development of China’s economy; the normalization of epidemic prevention and the control of COVID-19 have put forward urgent demands on social infrastructure configuration, especially with regard to the health institutions. Therefore, under the new situation, how to incorporate the carbon peak and carbon neutral requirements into the current “dual evaluation” (RECC evaluation and land development suitability evaluation) system; explore evaluation indicators with local characteristics; coordinate the relationship between resources, environment, ecology, and socio-economic development; coordinate the spatial planning and construction of the land; and reasonably allocate regional resources and sustainable green development of the regional economy has become an issue that must be solved on China’s path to reaching the level of the medium-developed countries by the middle of the 21st century.

This paper aims to guide territorial spatial planning from the perspective of the RECC evaluation results under the new situation faced by China; it innovatively incorporates carbon peak and carbon neutral indicators into the RECC evaluation index system; readjusts the weighting of the economic and social indicators, especially the medical system, so that the planning follows the principles of development and protection side by side; proposes planning strategies; and provides references for other socio-economic conditions. The spatial planning of other provinces with similar socio-economic conditions is proposed as a reference. Based on this, Shaanxi Province, one of China’s energy security bases, is used as the study area to construct an RECC evaluation index system in line with China’s high-quality development strategy, adopting the TOPSIS model based on the entropy weight method to analyze the factors influencing the RECC of Shaanxi Province from 2015 to 2020, including the overall level, spatial differences, and the carrying status, and to identify the shortcomings and then analyze the regional dynamic change characteristics and sustainable development trends. Finally, the FLUS model is used to simulate the spatial layout under the optimal scenario in order to provide a reference for the spatial planning of Shaanxi Province in the context of ecological civilization.

2. Literature Review

The study of the comprehensive RECC originated in the 1970s and refers to the scale of economic and social activities that can be carried by a region’s resource endowment and environmental capacity under the premise that the natural ecological environment is not endangered and that a good ecosystem is maintained. Most of the existing studies study the evaluation content of the RECC from a macro perspective and via the single elements of land, water, and atmosphere [5].

In terms of single elements, various researchers have different focuses and different evaluation elements, such as tourism resources [6,7], urbanization [8], and land [9]; the most studied element is the water environment [10–13], and most scholars select three key factors from water quantity, water quality, and ecology to construct the water resource carrying capacity evaluation index system, using the method of comparison. Through the comparison of the index values and evaluation criteria, the worst-case scenario of the comprehensive carrying capacity of the water resources system is derived [14]. As for the research methods, the main methods used are the SDG perspective, the three-dimensional balance model [15], Euclidean distance, the Gray-TOPSIS model [16], a two-dimensional model [17], a system dynamics model, the improved fuzzy comprehensive evaluation method [18,19], etc. Guo Qian and other scholars study a practical coupled SA-PP assessment model, which takes into account all the factors affecting water resources comprehensively, based on the conceptual framework of driving force–pressure–state–impact–response–management. The water resource carrying capacity DPSIRM evaluation index system was constructed. On this premise, the coupled SA-PP model was constructed. However, this model has limitations in the use of objects and is relatively suitable for regional water resource environmental carrying capacity evaluation [20]. Other scholars take watersheds, oceans, or arid and semi-arid regions as the evaluation objects and evaluate the water resource environmental carrying capacity by establishing a fuzzy integrated evaluation model [21–25].

At the macro level, some scholars have made a deep investigation into the index system and evaluation methods of RECC at different levels [26–31]. For example, Dong Wen et al. constructed the evaluation index system of RECC in the provincial main function zoning from the two perspectives of resource attributes and environmental attributes, based on the existing calculation method of measuring natural total and joint scientific and technological strength to achieve the accuracy of the evaluation [26]. Wang Xuejun et al. discussed the evaluation of RECC at the municipal level, constructing the index system from the three aspects of resource status, environment, and social conditions, using GIS technology and the hierarchical analysis method, combined with the actual situation of the region, and using the state space method to establish the evaluation model. Based on the evaluation results, the development intensity of each county within the municipal area is discussed [30]. Lv Yihe et al. reviewed the research priorities of the comprehensive regional RECC, including a comprehensive evaluation index system, coordination of the relationship between humans and the land, exploration of comprehensive research methods, and attention to spatiotemporal dynamics. It is shown that the construction of an indicator system, a research scale, and the dynamic changes are still needed in the future to support the study of regional resources and social and ecological environmental sustainability [31]. In general, using the judgment of RECC to achieve the optimal allocation of regional resources is one of the main ideas for solving the contradiction between the current situation of regional development and the development requirements; the evaluation of RECC largely restricts the territorial spatial planning. The relationship between the resource environment, the economy and society, and the territorial spatial planning is shown in Figure 1.

However, the existing RECC studies are mostly single-factor evaluations for land resources and water resources, and the environmental carrying capacity itself is characterized by the complexity and diversity of influencing factors. In addition, most of the studies are based on smaller spatial scale evaluation [32]. In summary, the evaluation methods of RECC are not unified; the research on exploring the mechanism of the role of the resource and environment elements and socioeconomic elements is weak; the research on the multi-factor comprehensive evaluation model of RECC needs to be deepened [33]. In the world, the concept of "territorial space planning" has not been put forward directly, but various spatial planning systems, such as regional planning [34], urban planning [35], land use planning [36], landscape planning [37], habitat management planning [38], etc., are taken as the most useful. However, all the kinds of spatial planning are relatively independent and even contradictory; so, much of the literature discusses their convergence or integration. For example, Lopes et al. [39] thought that city planning encompassed disciplines related to socio-economics, land use, transport, the environment, and others. A number of guiding documents and standards marked by Several Opinions of the Central Committee of the Communist Party of China and the State Council on Establishing and Supervising the Implementation of the Territorial Space Planning System (issued in 2019, hereinafter referred to as the Opinions) have been issued one after another. The Opinions point out that production space, living space, and ecological space (production–living–ecological, PLE) should be distributed scientifically and propose to optimize urban space, agricultural space, and ecological space (urban–agricultural–ecological, UAE) from the strategic level. For the research of UAE space, which is mainly based on the spatial demarcation of UAE space, the evolution characteristics, scale structure [40], and spatial layout [41] were studied. Some scholars have conducted a series of studies on the optimal allocation of land use structures from a multi-objective trade-off and synergy perspective, using optimization algorithms such as multi-objective particle swarm [42–44], while others have conducted studies on the optimization of the quantitative structure and spatial layout of the national land space. However, there are fewer studies on the optimal allocation of land use space based on the evaluation of RECC, and the threshold setting of the constraints in the optimization of the quantitative structure of land use space lacks the judgment based on the carrying capacity of the resource and environmental factors, which forms the spatial optimal allocation that provides for the selection of options and the actual planning needs [45–47]. There is a certain gap between the provided optimal spatial allocation options and the actual planning needs.

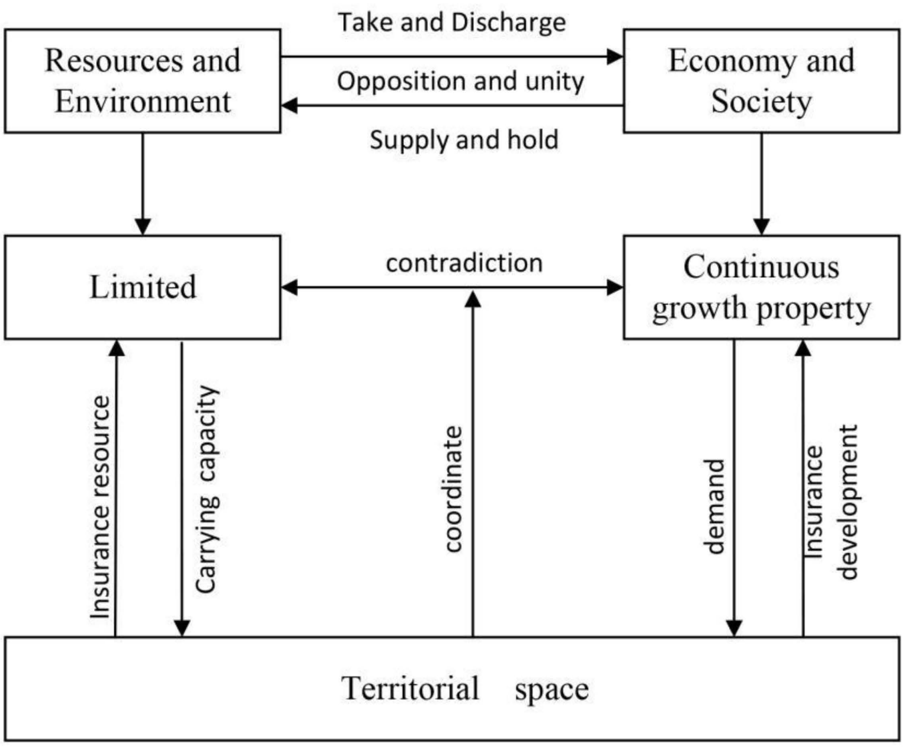

Figure 1. The relationship between resources, environment, economy and society, and territorial space planning.

3. Materials and Methods

3.1. Study Area

Shaanxi Province is the link between the western and central regions of China; the core province of the Silk Road; the key province under the “Belt and Road” Initiative; the central province of the Guanzhong Plain urban agglomeration; and the important base of China’s energy security, which is of great significance to China's economic development. The terrain of Shaanxi is high in the north and south and low in the middle. It is composed of various landforms, such as plateau, mountain, plain, and basin. The Loess Plateau accounts for 40% of the total land area of the province, which spans the Yellow River and the Yangtze River; the northern Shaanxi, Guanzhong, and the southern Shaanxi straddle three climatic zones. By the end of 2021, Shaanxi had a permanent population of 39.54 million. In 2021, Shaanxi Province achieved a gross regional product (GDP) of CNY 3 trillion. Behind the rapid economic and social development, there are a series of pressures. In particular, the current emphasis on the ecological environment and the commitment to the "double carbon" target pose great challenges to the new territorial space planning system. Therefore, Shaanxi is a typical case study and can be used as a reference for most developing provinces. The location map of the study area is shown in Figure 2.

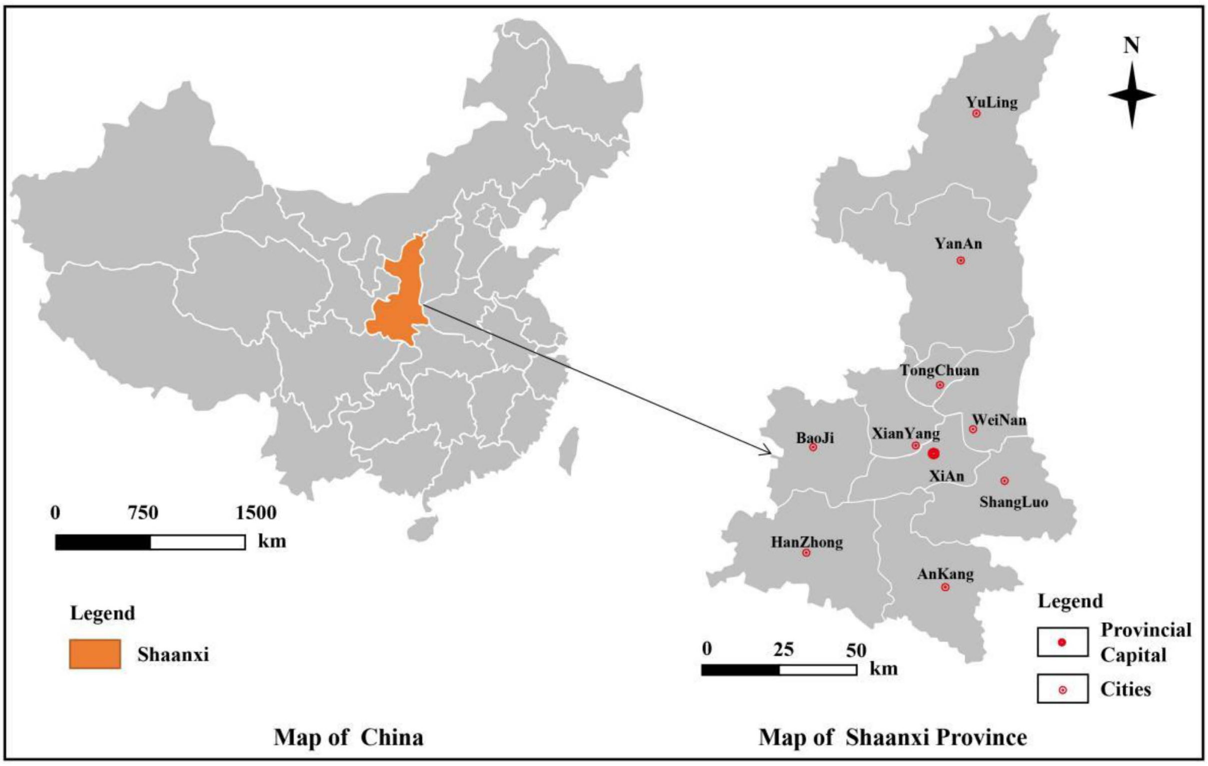

Figure 2. Geographical location of Shaanxi.

3.2. Data Sources

The data used in this study mainly include survey data, statistical data, and textual information. The survey data include the second national pollution source census data of Shaanxi Province and the greenhouse gas inventory data of Shaanxi Province from 2015 to 2020; the statistical data include the national economic statistical yearbook, the national economic and social development statistical bulletin, the water resources bulletin, and the air quality bulletin of Shaanxi Province; the textual information includes the ecological restoration plan of Shaanxi Province's national land space (2021–2035), etc. The missing data are replaced by the multi-year average value of each indicator (2035), etc. The missing data are replaced according to the multi-year average of local indicators.

3.3. Construction of RECC Index System

The stability of the ecosystem in Shaanxi Province is based on the balance between the resources, environment, society, and economy. This study takes RECC as the target layer and evaluates the RECC of Shaanxi Province from four aspects: the resource carrying capacity (RCC), the environment carrying capacity (ECC), the social carrying capacity (SCC), and the economic carrying capacity (EcCC); these are the criteria layers, and the criteria layers are both independent and interactive with each other to reflect the regional RECC. Finally, according to the regional characteristics of Shaanxi Province, 28 specific evaluation indicators are selected as the indicator layers to reflect the characteristic information of the resources and ECC of Shaanxi Province in combination with the requirements for green and high-quality development under the current stage of China's climate policy (Table 1).

Table 1. Shaanxi Province RECC evaluation index system.

Target Layer	Guideline Layer	Guideline Layer Description	Indicator Code	Indicator Layer	Unit	Properties
RECC	RCC(B1)	Reflects the ability of the resource system to support regional social development and the consumption of resources by the socio-economic system	C1	Arable land per capita	Hectare/person	+
			C2	Water resources per capita	Cubic meter/person	+
			C3	Standard coal production per capita	Ton/person	+
			C4	Average annual precipitation	mm	+
			C5	Average temperature	°C	+
			C6	≥10 °C accumulation temperature	°C	+
			C7	Energy consumption of CNY 10,000 GDP	Tons of standard coal/CNY 10,000	−
			C8	Water consumption of CNY 10,000 GDP	Cubic meter/CNY 10,000	−
			C9	Guaranteed recovered reserves	10,000 tons of standard coal	+
	ECC(B2)	Reflects the pollution caused by the region's socio-economic development to the environment and the degree of treatment	C10	Forest cover	%	+
			C11	Greenhouse gas emissions	10,000 tons	−
			C12	Industrial wastewater discharge	10,000 tons	−
			C13	SO_2 emissions	10,000 tons	−
			C14	Comprehensive utilization rate of industrial solid waste	10,000 tons	+
			C15	Sewage treatment rate	%	+
			C16	Harmless disposal rate of domestic waste	%	+
			C17	Average slope	Degree	−
	SCC(B3)	Reflects the current social development of the region and people's living standards and the social pressure it brings	C18	Population density	People per square kilometer	−
			C19	Housing floor area per capita	Square meter/person	+
			C20	Green space per capita	Square meter/person	+
			C21	Urbanization rate	%	−
			C22	Health institutions	Individual	+
			C23	Engel coefficient of urban residents	%	−
			C24	Engel coefficient of rural residents	%	−
	EcCC(B4)	Reflects the economic strength and industrial composition of the region and is the economic basis for other subsystems of the region	C25	GDP per capita	CNY	+
			C26	The proportion of total output value of tertiary industry	%	+
			C27	Disposable income of urban residents	CNY	+
			C28	Per capita net income of farmers	CNY	+
			C29	Total retail sales of social consumer goods	CNY 10,000	+
			C30	Mining industry as a share of regional GDP	%	−

3.4. Entropy Power Method

In the comprehensive evaluation, the weights of the index system determined by the entropy method can objectively and truly reflect the implicit information in the original data, effectively avoiding the bias caused by human factors, and the index weight values thus obtained have higher credibility and accuracy than the subjective assignment method [48]. Therefore, this study adopts the entropy weight method to determine the index weights of the resources and ECC, and its main calculation steps are shown in Appendix A.

3.5. TOPSIS Model

The TOPSIS model is the "approximation to ideal solution ranking method", which is a common decision-making technique in system engineering to solve multi-attribute or multi-criteria decision problems; it is a comprehensive evaluation method using distance as the evaluation criterion [49]. The main calculation steps are shown in Appendix A.

3.6. Multiple Linear Regression (MLR)

Based on the standardization of the original data, this paper constructs a multiple linear regression equation with RECC, ECC, SCC, and EcCC as the independent variables. The regression coefficients obtained reflect the importance of the corresponding independent variables. See Appendix A for the main calculation steps.

3.7. FLUS Model

The FLUS model is an integrated model based on the traditional CA model [50]; it has the dual characteristics of considering both "top-down" macro-driven and "bottom-up" micro-evolution, and it can efficiently simulate the future land use pattern under the influence of natural and human activities [51]. The model setting refers to the results of the relevant research [52,53], which will not be repeated in this paper.

4. Results

4.1. Analysis of Factors Affecting the Carrying Capacity of Resources and Environment

4.1.1. Analysis of Indicator Weights

The calculation of the indicator weights is carried out under the TOPSIS model based on the entropy method. The original data are standardized by constructing a standardized evaluation matrix V and are then standardized by standardization to obtain a standardized matrix R. The entropy method is used to calculate the weights of each detailed indicator. Equations (A1)–(A9) are the specific formulas. The results of the calculation of the weight of each detailed index of the RECC evaluation index system of Shaanxi Province are shown in Table 2.

Table 2. Index weight values for the evaluation of RECC of Shaanxi Province.

Indicators	ω_j	Indicators	ω_j
C1	0.0509	C16	0.0232
C2	0.0603	C17	0.0252
C3	0.0325	C18	0.0227
C4	0.0226	C19	0.0136
C5	0.0226	C20	0.0276
C6	0.0255	C21	0.0486
C7	0.0326	C22	0.0558
C8	0.0241	C23	0.0422
C9	0.0469	C24	0.0348
C10	0.0562	C25	0.0549
C11	0.0436	C26	0.0356
C12	0.0124	C27	0.0343
C13	0.0294	C28	0.0312
C14	0.0286	C29	0.0261
C15	0.0265	C30	0.0295

According to the index weights, the highest factor affecting the comprehensive level of RECC is C2 (per capita water resources), accounting for 0.0603, followed by C10 (forest coverage), accounting for 0.0562, C22 (sanitary institutions), accounting for 0.0558, and C25 (per capita GDP), accounting for 0.0549; the lowest factor is C12 (industrial wastewater discharge), accounting for 0.0124. Therefore, if we analyze the above indicators, the amount of water resources per capita is used to reflect the water resource carrying capacity of the region; the water resources content is important for the quality development of the habitat. In the time dimension, the per capita water resources show an increasing level from 2015 to 2020. The increase in forest cover is important for air purification, climate regulation, and biodiversity enhancement. In 2012, the provincial government of Shaanxi Province proposed the ecological construction strategy of "gardening in Guanzhong, greening the plateau in northern Shaanxi, and foresting the mountains in southern Shaanxi." In 2019, China launched a new round of territorial spatial planning, which clarifies the natural ecological space, the agricultural space, and the urban space from the institutional level. By 2021, the forest coverage rate in Shaanxi will have continued to increase, rising to over 45%, and the comprehensive vegetation cover of the grasslands will exceed 60%. It not only improves the biodiversity of Shaanxi Province, but also provides an important guarantee for Shaanxi Province's ability to cope with climate change under the new situation. The health institutions can be used to measure the level of RCC, and the larger the indicator, the higher the improvement of the level of the comprehensive development of society. From the index data, it can be obtained that the number of health institutions grows with the change of the time dimension. Industrial wastewater discharge has a negative effect on the RECC level, and a higher value of this indicator indicates a greater degree of pollution of the environment. With the continuous increase in the industrialization level, the industrial wastewater discharge continues to decline, indicating that the environmental carrying capacity of Shaanxi Province is gradually improving.

4.1.2. Multiple Linear Regression Model Analysis

Based on the calculation results in Table 2, the TOPSIS model was used to construct the evaluation matrix, and then, the positive and negative ideal values were determined according to Equations (A11) and (A12). Based on the index values and the annual average values of Shaanxi Province and its 10 prefecture-level cities (excluding the Yangling Demonstration Zone) from 2015 to 2020, the distance between the RECC and the positive and negative ideal values is calculated by the Euler calculation method, and the RCC, ECC, SCC, and EcCC indexes of Shaanxi Province and each city in the RECC guideline layer are finally obtained. The results are shown in Tables 3 and 4.

Table 3. 2015–2020 Shaanxi Province's RECC.

Year	2015	2016	2017	2018	2019	2020
RCC	0.1309	0.1466	0.1818	0.1940	0.2050	0.2097
ECC	0.1121	0.1213	0.1361	0.1509	0.1626	0.1749
SCC	0.0769	0.1017	0.1219	0.1427	0.1063	0.0902
EcCC	0.0675	0.0966	0.1335	0.1698	0.2000	0.2247
RECC	0.3873	0.4662	0.5733	0.6573	0.6739	0.6995

According to Table 3, a multiple linear regression model was established to reflect the mechanism of the ecological footprint driven by the resource, environmental, social, and economic factors, with the value of the RECC of Shaanxi Province in 2015–2020 as the dependent variable and the combined value of the four subsystem criteria as the independent variables. Then, the multiple linear regression model was obtained as follows.

$$Y = 0.686b1 + 0.334b2 + 0.197b3 + 0.428b4$$

where b1, b2, b3, and b4 correspond to the four criteria layers in Table 1, reflecting the influences of the resource, environmental, social, and economic factors in the process of driving the change of the RECC. The above equation shows that resource factors have the greatest influence on the RECC, followed by the economic factors.

Table 4. Average RECC of Shaanxi Province and prefecture-level cities, 2015–2020.

Province and City	Guideline Layer				Target Layer	Sequence Position
	RCC	ECC	SCC	EcCC	RECC	
Shaanxi	0.2462	0.1232	0.1202	0.1806	0.6702	/
Xi'an	0.1726	0.2198	0.2026	0.2029	0.7979	1
Xianyang	0.1460	0.2001	0.1340	0.1736	0.6537	2
Baoji	0.1648	0.1436	0.1353	0.1645	0.6082	3
Tongchuan	0.1444	0.1768	0.0642	0.1523	0.5377	4
Ankang	0.1711	0.2122	0.0914	0.0547	0.5294	5
Yulin	0.1528	0.1528	0.0755	0.1471	0.5282	6
Weinan	0.0945	0.2043	0.0894	0.1145	0.5027	7
Hanzhong	0.1525	0.1920	0.0509	0.0748	0.4702	8
Shangluo	0.1269	0.1336	0.0586	0.0962	0.4153	9
Yan'an	0.1021	0.0962	0.0635	0.1338	0.3956	10

4.2. Analysis of RECC Level

The comprehensive RECC level of Shaanxi Province is shown in Figure 3; the overall resource and environmental comprehensive carrying capacity level of Shaanxi Province shows an upward trend from 2015 to 2020. The minimum value of the overall RECC level of Shaanxi Province is 0.3873 in 2015; the maximum value of 0.6995 is in 2020, with an annual growth rate of 0.0624, and after 2019, the growth rate slows down. Figure 4 shows the dynamic distribution of the RECC subsystem in Shaanxi Province. It is intuitively derived from the figures, which, in the time dimension, the EcCC, RCC, and ECC subsystems, all show an increasing trend; the SCC subsystem shows an obvious decreasing trend after 2019, which may be related to the outbreak of COVID-19. The EcCC subsystem increases from 0.0675 in 2015 to 0.2247 in 2020, maintaining an increasing trend year by year. The economic development is a double-edged sword; on the one hand, the economic development will inevitably cause the consumption of resources, and in addition, the economic development will inevitably put pressure on the environment. However, with the development of the economy, it can also improve the efficiency of resource utilization, and the country will have more economic ability to manage the environment [48]. For example, the RECCy subsystem increases from 0.1309 in 2015 to 0.2097 in 2020, and the environmental carrying capacity subsystem increases from 0.1121 in 2015 to 0.1749. The RCC subsystem and the environmental carrying capacity subsystem show a fluctuating upward trend in general, which indicates that the positive effect of the level of economic development power and RECC is more than the negative effect.

4.3. Analysis of Regional Differences in RECC

According to Table 4, the annual average RECC of Shaanxi Province and the prefecture-level cities is graded using the ARCGIS natural interruption point grading method, and the RCC is divided into five grade types: high carrying area, higher carrying area, medium carrying area, lower carrying area, and low carrying area.

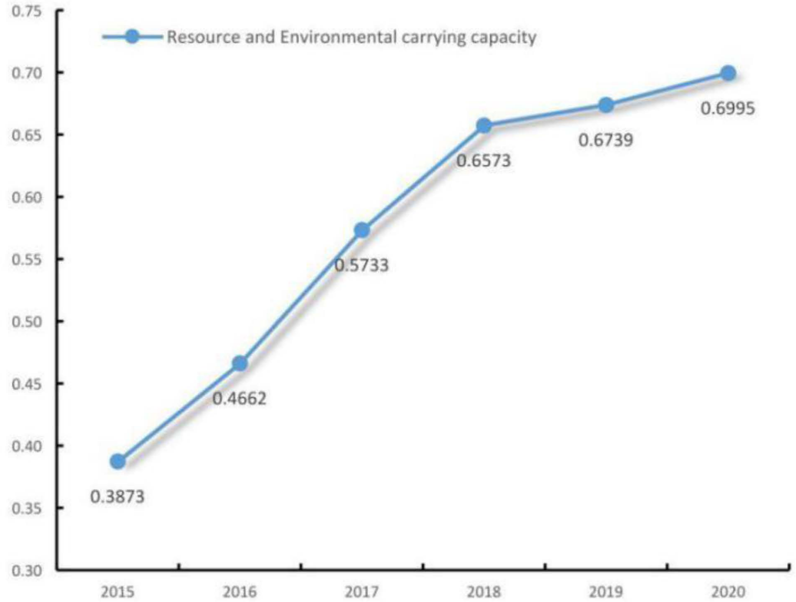

Figure 3. RECC of Shaanxi.

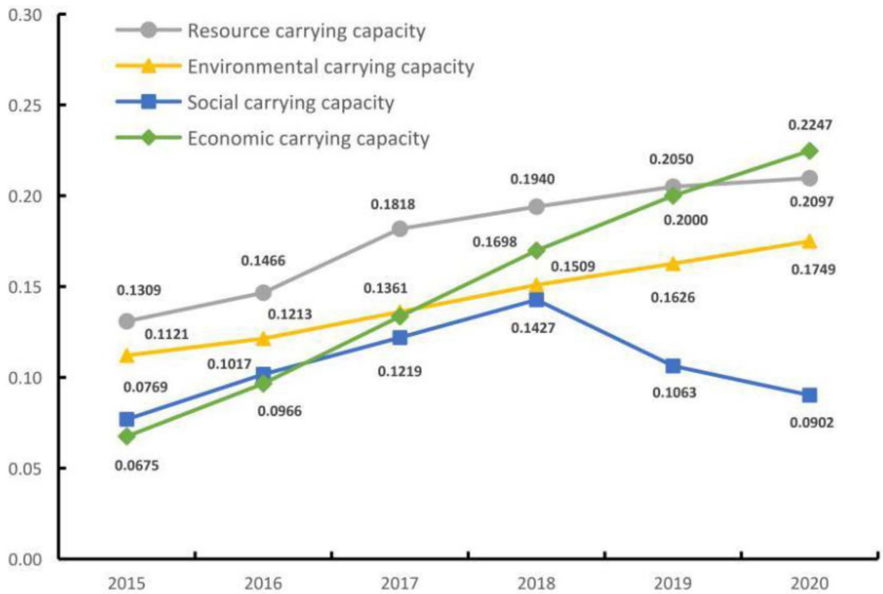

Figure 4. Dynamic distribution of RECC subsystem in Shaanxi Province.

According to the calculation results, the spatial distribution of the resource and environment bearing capacity of Shaanxi Province is given (Figure 5); it shows that the overall spatial distribution of Shaanxi's comprehensive RECC shows the characteristics of being high in Guanzhong, second in northern Shaanxi, and low in southern Shaanxi. Guanzhong has the highest resource supply bearing, while northern Shaanxi has the higher resource supply and socio-economic bearing capacity, and southern Shaanxi has the higher environmental bearing capacity because it is backed by the Qinling Mountains, but all the other bearing capacities are relatively low.

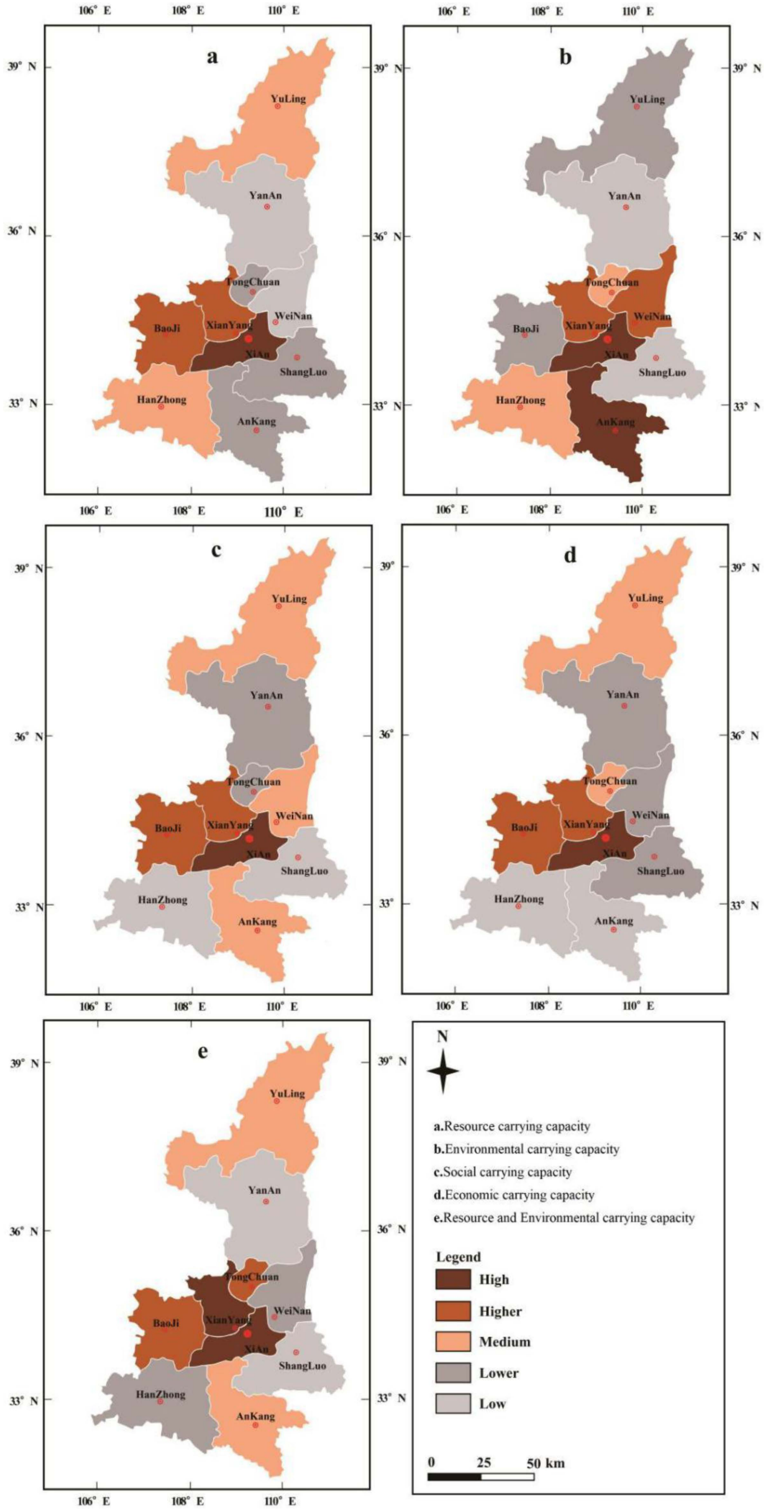

Figure 5. Spatial distribution of annual average RECC.

According to Figure 6, it can be found that economic development and social progress and environmental support are the two decisive factors for Xi'an to become a high-value area of RECC in the province, and its contribution to the comprehensive carrying capacity assessment value reaches 78%, while the RCC assessment value is only 0.1726 points, and this is its contribution to the comprehensive assessment value. This fully illustrates that the RCC is the shortcoming in the regional economic development of Xi'an.

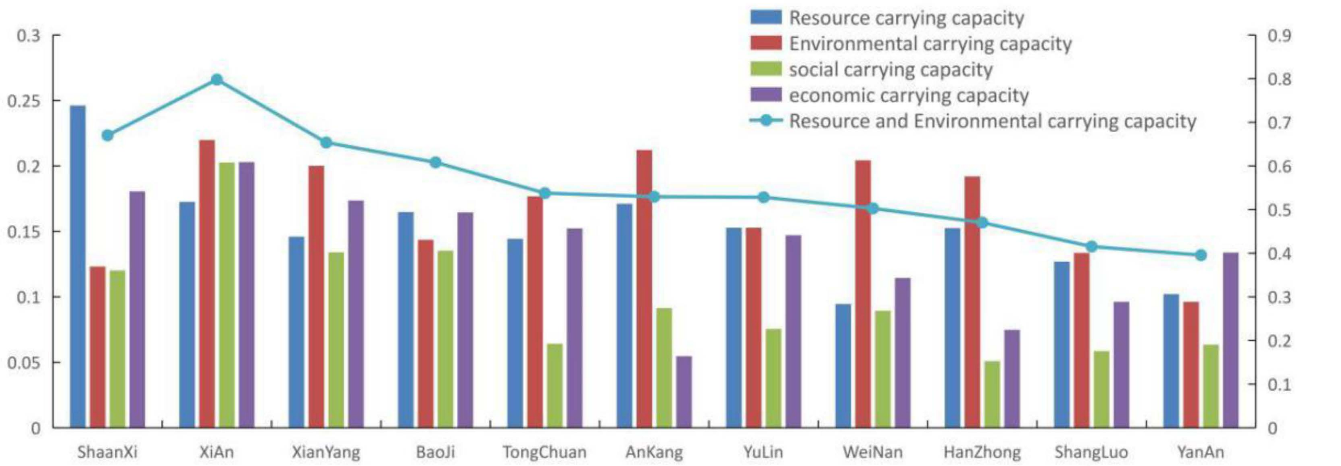

Figure 6. Comparison of the dynamic distribution of the average annual RECC of Shaanxi Province and prefecture-level cities from 2015–2020.

In terms of impact intensity, the RECCs of Xianyang, Tongchuan, Ankang, Yulin, and Hanzhong are all influenced by resource abundance and environmental support. Baoji City is influenced by resource abundance, economic development and social progress, and environmental support; Weinan City is mainly influenced by environmental support. Xianyang City has abundant resources and rapid economic development and is supported by environmental protection, which makes its RECC slightly lower than the provincial RECC. Ankang City and Hanzhong City are both located in the south of Shaanxi Province and are rich in resources, but their RECCs are lower than that of the provincial area due to economic development and environmental support. Weinan City has a lower RECC than the provincial area mainly due to its lower economic development and social progress assessment value. Tongchuan is located in the central part of Shaanxi Province, with perfect urban infrastructure and fast economic development, but its RECC is lower than that of the provincial area due to its small area; Yulin is a bordering area of five northwestern provinces and is particularly rich in mineral resources.

Yan'an City and Shangluo City are low-value areas for provincial resource and environment bearing capacity. From the viewpoint of influencing factors, the resource and environment bearing capacity of Yan'an City is affected by the resource abundance, economy, society, and environmental support; resource abundance and environmental support are the decisive factors for the resource and environment bearing capacity of Shangluo City, and the sum of their contribution to its resource and environment bearing capacity evaluation value is about 73%; economic development and social progress are the shortcomings of economic development in Shangluo City. The resource abundance, economic and social progress, and environmental support assessment values of Yan'an and Shangluo are lower; so, their RECCs are lower than that of the provincial area.

4.4. Analysis of the Bearing State of Resources and Environment

The resource and environment bearing state is the comparison between the bearing pressure and the bearing capacity, which is expressed by the resource and environment bearing rate. In this paper, the positive indicators in the comprehensive evaluation system of the resource and environment bearing capacity represent the bearing capacity, and the negative indicators represent the bearing pressure. According to the method of resource and environment bearing state classification by Cui Haitao [54], a resource and environment bearing rate of ≤ 0.8 is the surplus state; a resource and environment bearing rate between 0.8 and 1 and a resource and environment bearing pressure difference greater than 0 is the equilibrium state. There is also the resource and environment bearing rate of ≥ 1 and the resource and environment bearing pressure difference. The resource and environment bearing ratio and bearing status of Shaanxi Province and its cities are shown in Table 5.

Table 5. Shaanxi Province's resource and environmental carrying state.

Province and City	Carrying Capacity	Carrying State
Ankang	0.4256	Surplus
Xi'an	0.5207	Surplus
Hanzhong	0.5869	Surplus
Baoji	0.6543	Surplus
Shangluo	0.7810	Surplus
Xianyang	0.8358	Balance
Yan'an	0.9326	Balance
Yulin	1.3682	Overloading
Weinan	1.4763	Overloading
Tongchuan	1.6032	Overloading
Shaanxi Province	0.8294	Balance

The resource and ECC of Xi'an, Ankang, Baoji, Hanzhong, and Shangluo cities are in surplus. Xi'an City has superior comprehensive conditions for urban development, and its resource and ECC are high. Baoji City has a strong industrial base and is close to Xi'an City, sharing resources with Xi'an City, with faster economic development and higher RECC; Hanzhong City is rich in mineral resources, with faster economic development but weaker environmental support; Shangluo City is rich in natural resources, with higher economic development potential but weaker environmental protection support. These five cities have a surplus of resources and environmental carrying capacity, and their future development should be healthy and orderly, with their development protected.

The resource and environment carrying rates of Xianyang City and Yan'an City are in a balanced state. Yan'an City has a large amount of land and a small population, and the population pressure is low. These two cities are in a balanced state in terms of the resource and environment carrying rate and should pay more attention to economic development in the future under the premise of protecting the environment.

The resource and environmental carrying rates of Yulin, Weinan, and Tongchuan are in an overload state. The economic development model of Yulin City has changed from a single agricultural model to a comprehensive development model, and the rapid economic development has resulted in the excessive consumption of resources and a high pressure of environmental pollution. Tongchuan is the smallest prefecture-level city in Shaanxi Province, with limited resources and serious environmental pollution. These three cities are in the overload state of the resource and environmental carrying rate, and their future development should focus more on the protection of the environment and should find the way of harmonious development of resources, the environment, and the population without sacrificing the environment.

4.5. Optimization of Territorial Spatial Structure Based on FLUS Model

In this study, the FLUS model is used to simulate the spatial layout of land use. Then, considering the influence of neighborhood influence factors, inertia coefficients, and conversion costs, the land use types with high suitability probability are assigned to the raster within the CA iteration time, and the land use layout simulation is finally realized. The spatial distribution of land use in 2020 is obtained by using the FLUS model simulation with the current status of land use spatial distribution in 2015 as the base period data, and the overall accuracy of the simulation is verified to be 90.45%; the Kappa coefficient is 0.6587; so, the model accuracy meets the requirements. Therefore, according to the "Shaanxi Province General Land Use Plan", "Shaanxi Province Land Space Ecological Restoration Plan (2021–2035)", and Shaanxi Province's "14th Five-Year Plan", the total energy consumption and energy consumption per unit of GDP is calculated; at the same time, it should be considered that the main limiting factor of Shaanxi Province's natural endowment on the background resource and environment bearing capacity is water resources. At present and for a long time in the future, the shortage of water resources will affect and determine the carrying capacity of the regional resources and environment and thus constrain the spatial structure and distribution of the regional land. Therefore, based on the current situation of the land use area, we simulate the spatial distribution of Shaanxi Province after the adjustment and optimization of land use zoning (Figure 7).

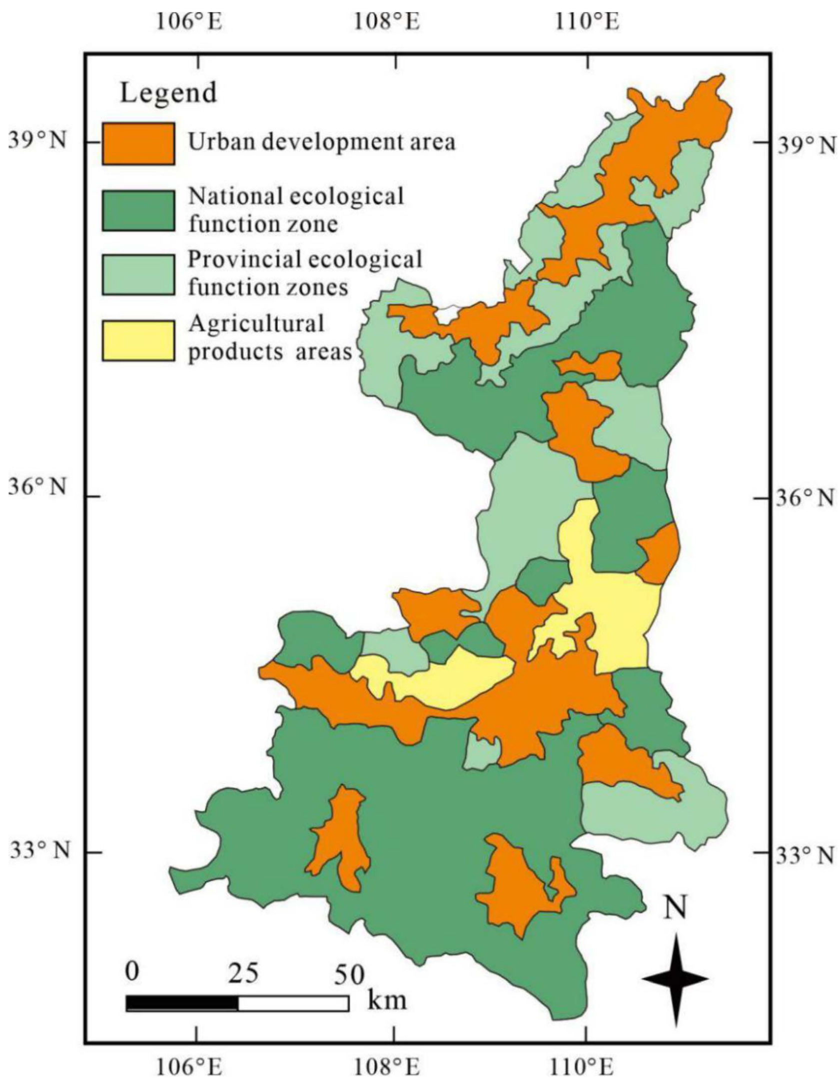

Figure 7. The distribution of territorial spatial regionalization after adjustment and optimization in Shaanxi Province.

From Figure 7, it can be seen that the Guanzhong Plain City Cluster, which is an important national economic growth pole, the northern area of Yulin, which is an important national energy chemical base, and the regional central cities are the core of the urbanized development area; the main production areas of agricultural products are mainly concentrated in the northern area of the Guanzhong Plain City Cluster, including the main grain production area of Guanzhong and the northern Weibei grain and fruit farming and animal husbandry area. The ecological importance and ecosystem vulnerability of the western bank of the Yellow River in the Qinba Mountains in southern Shaanxi and the Baiyu Mountains in northern Shaanxi are high and play an important role in maintaining China's ecological security pattern; so, the area is basically positioned as a national key ecological function area. The Huanglong Mountain and the Ziwu Mountain areas of the Loess Plateau and the wind and sand area along the Great Wall in northern Shaanxi are mostly provincial key ecological function areas.

5. Discussion

This study introduces a multi-factor comprehensive evaluation model to quantitatively analyze the comprehensive RECC of Shaanxi Province under the new situation of China's climate policy and high-quality economic development, and with the help of the ARCGIS visual expression display, the results show more intuitively and clearly the spatial optimization of Shaanxi Province based on the comprehensive resource and environmental carrying capacity of the country. At the research level, it fills the gap of the incomplete selection of factor factors and ensures that the model factors can accurately reflect the regional and contemporary reality. This study is different from the "dual evaluation" study by mainstream Chinese scholars for the current practical work [55], where the evaluation index system is selected by conceptual model, which is somewhat subjective and not highly replicable [22] Compared with the three-dimensional balance model [15], the system dynamics model, and the improved fuzzy comprehensive evaluation method [18,19] used in the evaluation of resource and environmental carrying capacity, the entropy-TOPSIS model effectively avoids the bias caused by human factors.

However, there are still some limitations in this study. First, resources, environment, and social economy are a unified whole, and how to carry out the optimal allocation among the four still needs further analysis of the complex mechanisms among the various resource, social, and economic evaluation indicators and between them and the comprehensive carrying capacity of the resources and environment. Secondly, the relationship between Shaanxi Province as a national energy chemical base and the resources and environment is necessarily not equivalent to the provinces with economic development or ecological protection as the main function. Therefore, it is also necessary to fully consider the geographical differences in constructing the system when promoting the application of the model, which requires strengthening the analysis of the trade-offs between the index elements and between them and the objective regional reality, so as to provide a basis for decision making on regional development and environmental protection. Finally, this study mainly considers the regional attributes of urban–agricultural–ecological space in the process of the spatial structure optimization of national land using the FLUS model, and it lacks the spatial optimization of production–living. The spatial optimization of the production–living–ecological function is not considered comprehensively.

Similarly, some ideas for further research were found in the process of this study. Firstly, in terms of the comprehensive evaluation of the resources and the environment, most scholars only stay in the study of carrying capacity and less in the study of carrying potential, the core reason being the difficulty in grasping the complex external factors, especially the policy factors, that may affect the carrying capacity. However, it is often only by mapping the potential conditions of the resources and the environment that we can better point out the direction for the planning of national land space and so on. Secondly, the change of land use type involves both carbon increase and carbon reduction. Therefore, in the process of land space optimization research, we can adjust the carbon sink land, such as forest land and cultivated land; the land for photovoltaic, wind power, and other renewable energy sources; and the proportion of land used for industrial construction and other major carbon emission sources. Then, we can realize the optimization of land space under carbon constraints, and the simulation can maximize the ecological and economic benefits.

6. Conclusions

This paper constructs a comprehensive evaluation index system of RECC under the new situation of climate policy and high-quality economic development; it analyzes the factors influencing the resource and environment bearing capacity, the overall level, the spatial difference, and the bearing status by using the TOPSIS model based on the entropy weight method, and it identifies the shortcomings; then, it analyzes the characteristics of regional dynamic change and the sustainable development trend, and finally, it simulates the optimal spatial pattern by using FLUS model. Taking Shaanxi Province as an example, the index weights indicate that the highest factors affecting the comprehensive level of the resource and environmental carrying capacity are the amount of water resources per capita, forest coverage, and sanitation institutions, and the lowest is industrial wastewater discharge. The forest coverage not only improves the biodiversity of Shaanxi Province, but also provides an important guarantee for Shaanxi Province's ability to cope with climate change under the new situation. The spatial bearing capacity of the resources and the environment in Shaanxi Province as a whole shows the characteristics of being high in Guanzhong, second in northern Shaanxi, and low in southern Shaanxi. Guanzhong has the highest resource supply capacity, while northern Shaanxi has a higher resource supply and socio-economic capacity, and southern Shaanxi has a higher environmental capacity because of the Qinling Mountains, but the rest of the capacity is relatively low. The Guanzhong Plain City Cluster, which is an important economic growth pole in China, and the northern part of Yulin, which is an important energy chemical base in China, as well as the regional central cities, comprise the core of the urbanized development area; the main production areas of agricultural products are mainly concentrated in the northern part of the Guanzhong Plain City Cluster; the Qinba Mountains in southern Shaanxi and the western bank of the Yellow River in the Baiyu Mountains in northern Shaanxi are the key ecological function areas.

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Appendix A

Appendix A.1. Entropy Power Method

The entropy weighting method main calculation steps are as follows:

(1) Construction of standardized evaluation matrix.

Step 1: Establish the original series matrix V = $(v_{ij})_{m\times n}$ of the RECC of Shaanxi Province according to the selected indicators; v_{ij} denotes the original value of the jth indicator in the ith year; m denotes the year; and n denotes the indicator; so, the original evaluation indicator matrix is shown in Equation (A1).

$$\mathrm{V} = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix} \tag{A1}$$

Step 2: The raw data in the indicators are standardized using the polarization method according to the positive and negative nature of the indicators. For the positive (benefit) indicators, the calculation is performed using Equation (A2), and for the negative (cost) indicators, the calculation is performed using Equation (A3). In order to eliminate the influence of negative values on the calculation, the standardized values are shifted, where $\min(\mathrm{v}_{ij})$ denotes the minimum value of the original data, $\max(\mathrm{v}_{ij})$ denotes the maximum value of the original data, and H is the magnitude of the indicator shift, which is generally taken as 1. Therefore, the standardization matrix R is obtained.

$$\mathrm{S}_{ij} = \frac{\mathrm{v}_{ij} - \min(\mathrm{v}_{ij})}{\max(\mathrm{v}_{ij}) - \min(\mathrm{v}_{ij})} \tag{A2}$$

$$\mathrm{S}_{ij} = \frac{\max(\mathrm{v}_{ij}) - \mathrm{v}_{ij}}{\max(\mathrm{v}_{ij}) - \min(\mathrm{v}_{ij})} \tag{A3}$$

$$\mathrm{S}'_{ij} = \mathrm{S}_{ij} + H \tag{A4}$$

$$\mathrm{R} = \begin{bmatrix} s'_{11} & s'_{12} & \cdots & s'_{1n} \\ s'_{21} & s'_{22} & \cdots & s'_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ s'_{m1} & s'_{m2} & \cdots & s'_{mn} \end{bmatrix} \tag{A5}$$

(2) Calculation of indicator weights. Step 1: Calculate the weight of the j indicator in the i sample (i.e., year i) by using the weighting method p_{ij}; the specific formula is shown in Equation (A6).

$$p_{ij} = \frac{\mathrm{S}_{ij}}{\sum\limits_{i=1}^{n} \mathrm{S}_{ij}} \qquad (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \tag{A6}$$

Step 2: Calculate the entropy value of the jth indicator e_j; see Equation (A7). M is the number of evaluation samples; calculate the redundancy value d_j; see Equation (A8).

$$\mathrm{e}_j = -\frac{1}{\ln \mathrm{M}} \sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{A7}$$

$$\mathrm{d}_j = 1 - \mathrm{e}_j \tag{A8}$$

Step 3: Calculate the weight of the jth indicator ω_j; the detailed calculation process is shown in Equation (A9).

$$\omega_j = \frac{\mathrm{d}_j}{\sum\limits_{i=1}^{m} \mathrm{d}_j} \tag{A9}$$

where p_{ij} denotes the weight of the jth indicator in the i-th sample (i.e., year i); e_j denotes the minimum information entropy; d_j denotes the redundancy value; and ω_j denotes the indicator weight.

Appendix A.2. TOPSIS Model

The TOPSIS model main calculation steps are as follows.

(1) Evaluation matrix construction. With the help of the weighting idea, the objectivity of the evaluation matrix is further improved, and the normalized weighted judgment matrix is constructed by multiplying the index weights determined by using the entropy weighting method ω_j with the normalized matrix.

$$\mathrm{Y} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} = \begin{bmatrix} s'_{11} \cdot \omega_1 & s'_{12} \cdot \omega_1 & \cdots & s'_{1n} \cdot \omega_1 \\ s'_{21} \cdot \omega_2 & s'_{22} \cdot \omega_2 & \cdots & s'_{2n} \cdot \omega_2 \quad s \\ \vdots & \vdots & \vdots & \vdots \\ s'_{m1} \cdot \omega_m & s'_{m2} \cdot \omega_m & \cdots & s'_{mn} \cdot \omega_m \end{bmatrix} \tag{A10}$$

(2) Positive and negative ideal solution determination. The normalized matrix can be determined by Equation (A11) with the positive ideal value Y^+, which represents the

maximum value of the jth indicator in year i, i.e., the optimal solution. The negative ideal value Y^- is determined by formula (A12), which represents the minimum value of the jth indicator in year i, i.e., the worst solution. The specific formula is as follows.

$$Y^+ = \{\max_{1\le j\le m} y_{ij} | j = 1, 2, \cdots, m\} = \{y_1^+, y_2^+, \cdots, y_m^+\} \quad (A11)$$

$$Y^- = \{\min_{1\le j\le m} y_{ij} | j = 1, 2, \cdots, m\} = \{y_1^-, y_2^-, \cdots, y_m^-\} \quad (A12)$$

(3) Calculation of distance. To calculate the distance of the scheme, the distance articles of the positive and negative ideals are calculated using the Euler calculation method. Let D_j^+ denote the distance between the jth indicator and y_i^+; see Equation (A13); let D_j^- denote the distance between the jth indicator and y_i^-; see Equation (A14).

$$D_j^+ = \sqrt{\sum_{i=1}^{m} (y_i^+ - y_{ij})^2} \quad (A13)$$

$$D_j^- = \sqrt{\sum_{i=1}^{m} (y_i^- - y_{ij})^2} \quad (A14)$$

(4) The closeness of the ideal solution is calculated. Let T_i be the closeness of the resource and environment bearing capacity of the northwest region in year i. Its value range is [0, 1]; when $T_i = 0$, the resource and environment bearing capacity is the lowest; when $T_i = 1$, the resource and environment bearing capacity is the highest; the larger T_i is, the closer to the optimal state of the resource and environment bearing capacity level. The detailed calculation process is shown in Equation (A15).

$$T_i = \frac{D_j^-}{D_j^+ + D_j^-},\ T_i \in [0, 1] \quad (A15)$$

Appendix A.3. Multiple Linear Regression (MLR)

The representation of the multiple linear regression model can be seen as a generalization of the one-dimensional linear regression model, which is generally represented as:

$$\Pi = \beta_0 + \beta_1 \nu_1 + \beta_2 \nu_2 + \ldots + \beta_m \nu_m + \xi \quad (A16)$$

where Π is the dependent variable, $v_1, v_2, \ldots, v_m$ are the independent variables, $\beta_0, \beta_1, \beta_2, \ldots, \beta_m$ are the regression coefficients, and ξ is the random error of the model. Assuming that there are n sets of observations, where the number of independent variables is m, then the multiple linear regression model can be expressed as:

$$\begin{cases} \Pi_1 = \beta_0 + \beta_1 \nu_{11} + \beta_2 \nu_{12} + \ldots + \beta_m \nu_{1m} + \xi_1 \\ \Pi_2 = \beta_0 + \beta_1 \nu_{21} + \beta_2 \nu_{22} + \ldots + \beta_m \nu_{2m} + \xi_2 \\ \cdots\cdots \\ \Pi_n = \beta_0 + \beta_1 \nu_{n1} + \beta_2 \nu_{n2} + \ldots + \beta_m \nu_{nm} + \xi_n \end{cases} \quad (A17)$$

A key issue in the multiple linear regression model is to calculate the estimates of the regression coefficients obtained. Similarly to the parameter estimation method of the same linear regression model, the parameter estimates of the commonly used multiple linear regression model are also least squares [56,57].

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