ISSN: 1813-4890

Synergistic Development and Attribution Analysis of Ecological Carrying Capacity and Industries in Xilin Gol League

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Abstract

Taking Xilin Gol League as an example, this study employs a coupling coordination model and a grey relational model to calculate the coupling coordination of the ecological carrying capacity and industrial development system from 2011 to 2021. Factor analysis is used to determine index weights. The study examines the temporal characteristics and driving factors of this coupling coordination to provide decision-making references for the ecological status and regionally high-quality coordinated development of Xilin Gol League . The results indicate that during the research period, the two systems transitioned from a state of basic discoordination to one of basic coordination, exhibiting an overall fluctuating upward trend. The coupling coordination ranged from 0.3284 to 0.6063. From 2011 to 2015, they were in a state of basic discoordination characterized by lagging economic development. Although from 2016 to 2021, they were generally in a state of basic coordination with economic development lagging behind, there was some improvement in the lagging development of industries from 2020 to 2021. In the ecological carrying capacity subsystem, the total urban water supply demonstrates the highest contribution rate to the coupling coordination of Xilin Gol League's ecological carrying capacity and industrial development system, with a relational degree of 0.758. Following this is the annual average precipitation, with a relational degree of 0.737, and thirdly, the total area of crop cultivation, with a relational degree of 0.675. In the industrial development system, the total output value of agriculture, forestry, animal husbandry, and fishery, per capita GDP, and per capita disposable income of urban residents are the most significant contributors to the system's coupling coordination, with relational degrees of 0.758, 0.697, and 0.671, respectively.

Keywords

Xilin Gol League, Ecological carrying capacity, ocial economy, oupling coordination degree. Grey correlation degree.

1. Introduction

Ecological carrying capacity refers to the self-sustaining and self-regulating ability of ecosystems, the capacity of resource and environmental subsystems for supporting and accommodating, as well as the intensity of sustainable socioeconomic activities and the population size capable of maintaining a certain standard of living [1].It determines the industrial structure, technological level, as well as the speed, scale, and overall magnitude of economic and social development in a region, serving as the most fundamental prerequisite for achieving sustainable development in an area [2].Once economic and social development surpasses ecological carrying capacity, it leads to a series of ecological and environmental issues [3]. The mutual coercion and evolution between ecological environment changes and economic and social development result in their mutual coupling [4]. Coupling coordination is the overall efficiency of ecological and economic social systems and measures the harmony of evolution within and between subsystems [5,6]. The coordination status is related to the ecological security and sustainable development of the region [7].

The theoretical framework of synergistic development between ecology and economy encompasses disciplines and theories such as ecology, resource science, economics, environmental science [8], as well as complex ecological system theory [9], environmental carrying capacity theory [10], and ecological-economic coordination theory [11]. These disciplines and theories are applied to the pursuit of sustainable development. Since the beginning of the 21st century, scholars have increasingly focused on the coordinated development of economic growth and ecological environmental protection. The Environmental Kuznets Curve (EKC) model proposed by scholars like Grossman and Krueger (1995) suggests a inverted "U" relationship between environmental protection and economic development [12]. Braimoh and Osaki (2010) and others have constructed an indicator evaluation system for sustainable urban land use by studying urban development [13].Nie Xiao et al. employed principal component analysis, analytic hierarchy process, and coupling coordination model to measure the degree of coordinated development among the environmental, economic, and social systems in Hubei Province [14]. Yang Hongjuan and Zhang Chenghao utilized system dynamics methods to evaluate the ecological civilization construction in Yunnan Province through a four-system model of "economy-society-resources-environment" [15]. Fan Xianxian and Zhou Yunlei calculated the coupling coordination degree between land use and the economic-social-environment system in 108 prefecture-level cities in the Yangtze River Economic Belt. They used various methods to analyze the spatiotemporal differentiation characteristics and driving factors, aiming to promote sustainable land use [16].

Xilin Gol League is one of the most important natural grassland grazing and animal husbandry bases in China. However, influenced by climate change and anthropogenic factors, the ecological degradation of Xilin Gol grassland deteriorated sharply at the end of the last century. Natural disasters such as sandstorms directly threatened the capital and even the entire North China region, leading to conflicts between industrial development and the ecological environment and the balance of grass and livestock in pastoral areas [17,1819]. In this context, this study takes Xilin Gol League from 2011 to 2021 as the research object, constructs an indicator system for ecological carrying capacity and the economic-social system, and uses a coupling coordination model to study the coupling coordination relationship and influencing factors between regional ecological carrying capacity and industrial development systems. This research aims to provide a basis for regional industrial development planning and regional sustainable development decision-making.

2. Research Area and Data Sources

2.1. Overview of the Study Area

The Xilin Gol League is situated in the central part of Inner Mongolia Autonomous Region, bordering Mongolia to the north, sharing boundaries with Ulanqab to the west, and neighboring Hebei Province to the south; it is connected to Chifeng, Tongliao, and Hinggan League to the east. It administers 2 cities, 1 county, 9 banners, and 1 administrative committee. The Xilin Gol grassland boasts abundant natural resources, featuring a variety of grassland types and a diverse range of flora and fauna, serving as a vital ecological barrier in North China. In 2022, the Xilin Gol League achieved a regional GDP of 114.865 billion yuan, representing a 3.8% increase over the previous year.

2.2. Source of Data

This article primarily measures the coordinated development of the ecological carrying capacity and industrial development subsystems in Xilin Gol League. It mainly involves data on the natural environment, ecological resource supply, environmental pollution, environmental governance, economic development, and social development in Xilin Gol League. The relevant data are obtained from the "Inner Mongolia Statistical Yearbook" and the "Xilin Gol League Statistical Yearbook" from 2012 to 2022. For missing statistical data, this study adopts data migration methods for supplementation.

3. Research Methodology

According to Wackernagel and Galli's definition of ecological carrying capacity, it is the capacity of the study area to support industrial and economic development through its agricultural land, water resources, forests, grasslands, minerals, and other resources, while accommodating the environmental emissions generated by economic development [20]. It constitutes an organic unity of resources and the environment within the region, mutually complementary, where resources possess environmental attributes, and the environment possesses resource attributes [7]. Industrial and social development are also intricately intertwined. Therefore, this paper measures the industrial development level of Xilin Gol League through economic and social indicators.

3.1. Establishment of Evaluation Index System

The index system mainly includes two major subsystems: ecological carrying capacity and industrial development in Xilin Gol League. Due to the diverse units and ranges of different evaluation indicators, direct analysis using raw values may lead to dominance by indicators with larger values, potentially weakening the impact of indicators with smaller values when significant differences exist among these indicators. To ensure the reliability of the results, it is necessary to standardize the raw data. In this study, the method of range normalization, calculated as the difference between the maximum and minimum values, is adopted to process the indicator data, thereby eliminating dimensional influences. The standardization method used is the range normalization approach：

$$X = \frac{x - \min(x)}{\max(x) - \min(x)} \text{, X as a positive indicator}$$

$$X = \frac{\min(x) - x}{\max(x) - \min(x)} \text{, X as a negative indicator}$$

In the equation, min(x) and max(x) represent the minimum and maximum values of indicator x, respectively. The weights of criteria layer and indicator layer are assigned using factor analysis. The specific weight calculation results are shown in Table 1.

Table 1 Weighting of Indicators for Assessing the Coordination between Ecological Carrying Capacity and Industrial Development Systems

System Objective Layer	Functional Layer	Weight	Specific Indicators	Type of Indicators	Weight
Ecological Carrying Capacity System	Natural Environment	0.1037	Annual Average Precipitation	Positive	0.0362
			Annual Average Temperature	Positive	0.0675

	Resource Supply	0.3197	Forest Coverage Rate	Positive	0.0611
			Total Cropland Area	Positive	0.0654
			Afforestation Area	Positive	0.0580
			Green Area	Positive	0.0668
			Total Urban Water Supply	Positive	0.0684
	Environmental Pollution	0.3233	Equivalent Pure Amount of Fertilizer Applied in Agriculture	Negative	0.0556
			General Industrial Solid Waste Generation	Negative	0.0663
			Industrial Wastewater Discharge Volume	Negative	0.0663
			Industrial Sulfur Dioxide Emissions	Negative	0.0638
			Industrial Exhaust Emissions Volume	Negative	0.0389
			Livestock Population at the End of June	Negative	0.0433
	Environmental Governance	0.2533	Effective Irrigated Area	Positive	0.0497
			Harmless Treatment Rate of Domestic Waste	Positive	0.0747
			Sewage Treatment Rate	Positive	0.0673
			Comprehensive Utilization Rate of General Industrial Solid Waste	Positive	0.0616
Economic and Social Development System	Economic Development	0.5581	Per Capita GDP	Positive	0.0738
			GDP Growth Rate	Positive	0.0699
			Proportion of Added Value of the Primary Industry	Negative	0.0714
			Proportion of Added Value of the Secondary Industry	Negative	0.0732
			Proportion of Added Value of the Tertiary Industry	Positive	0.0744
			Total Grain Production	Positive	0.0736
			Total Output Value of Agriculture, Forestry, Animal Husbandry, and Fishery	Positive	0.0717
			Total Social Fixed Asset Investment	Positive	0.0501
	Social Development	0.4419	Health Technical Personnel	Positive	0.0501

	Number of Students Enrolled in Various Types of Schools	Positive	0.0729
	Natural Population Growth Rate	Positive	0.0383
	Per Capita Disposable Income of Urban Permanent Residents	Positive	0.0680
	Per Capita Disposable Income of Residents in Agricultural and Pastoral Areas	Positive	0.0708
	Engel Coefficient of Household Expenditure for Permanent	Positive	0.0751
	Residents in Rural and Pastoral Areas	Negative	0.0749
	Urban-Rural Income Disparity Ratio	Positive	0.0419

3.2. Coupling Coordination Model

Coupling coefficient is commonly used to measure the strength of interactions between subsystems or elements within subsystems, focusing solely on the intensity of the interactions without considering their directionality. In contrast, coordination is used to gauge the degree of harmony between subsystems or elements within subsystems. It not only reflects the positive interactions between systems but also captures the trend of internal elements transitioning from disorder to coordination [21]. Coupling coordination reflects the degree of superiority in the relationships among the coupled parties, where high coordination implies a high level of positive interaction and mutual promotion among the coupled parties. Therefore, some scholars often introduce the concept of coordination when analyzing coupling coefficients to elucidate the state of coordinated development of the research object [22].

Through the coupling coordination of ecological carrying capacity and industrial development systems in Xilin Gol League, the mutual integration of elements between the two systems and within the systems is promoted, aiming to achieve organic integrity. During the process of system coupling, there exist interrelated interactive relationships between the system and the environment as well as within the system elements. The coupling degree between the ecological carrying capacity and industrial development systems within the system reveals the strength of their interaction during a certain period, while coupling coordination reflects the degree of alignment between these two major systems, providing an overall indication of their coordinated development level.

The formula for calculating the coupling coordination degree (D) is as follows:

$$D = \sqrt{C \cdot T}$$

$$C = \sqrt{\frac{f(x)g(x)}{[f(x)+g(x)]^2}}$$

$$T = \alpha f(x) + \beta g(x)$$

$$f(x)=\sum_{i=1}^{m} w_j y_j$$

$$g(y)=\sum_{j=1}^{n} w_j y_j$$

In the formula: D represents the coordination degree; C stands for the coupling degree; T denotes the comprehensive evaluation index of industrial development and ecological carrying capacity; f(x) and g(y) respectively represent the values of ecological carrying capacity change and industrial development level. Considering the actual situation of Xilin Gol League, ecological environment protection and industrial development are deemed equally important, hence both g and h are assigned values of 0.5. x_i and y_j denote the standardized values of ecological carrying capacity change and industrial development, while w_i and w_j represent the weights of ecological carrying capacity change and industrial development, determined using factor analysis.

Drawing on previous research on the coupling coordination among multiple systems [7], the types of coupling between changes in ecological carrying capacity and socio-economic development are classified into three main categories, four sub-categories, and twelve subtypes.

Table 2 Classification of Coupling Coordination Types between Changes in Ecological Carrying Capacity and Industrial Development

Index	Types of Coordinated Development	Subtypes	Types of Coupling Coordination
$0.8<D\leq 1$	Advanced Coordination	$x-y>0.1$	Advanced Coordination-Industrial Development Lag
		$x-y>0.1$	Advanced Coordination-Ecological Carrying Capacity Lag
		$0<\lvert x-y\rvert<0.1$	Advanced Coordination
$0.5<D\leq 0.8$	Basic Coordination	$x-y>0.1$	Basic Coordination-Industrial Development Lag
		$x-y>0.1$	Basic Coordination-Ecological Carrying Capacity Lag
		$0<\lvert x-y\rvert<0.1$	Basic Coordination
$0.3<D\leq 0.5$	Basic Discoordination	$x-y>0.1$	Basic Discoordination-Industrial Development Lag
		$x-y>0.1$	Basic Discoordination-Ecological Carrying Capacity Lag
		$0<\lvert x-y\rvert<0.1$	Basic Discoordination
$0<D\leq 0.3$	Severe Discoordination	$x-y>0.1$	Severe Discoordination-Industrial Development Lag
		$x-y>0.1$	Severe Discoordination-Ecological Carrying Capacity Lag
		$0<\lvert x-y\rvert<0.1$	Severe Discoordination

3.3. Grey Relational Analysis Method

Grey Relational Analysis is a highly active branch within the grey system theory. Its fundamental concept lies in determining the closeness of relationships between different sequences based on the geometric shapes of sequence curves. The basic approach involves transforming the discrete behavioral observation values of system factors into piecewise continuous broken lines through linear interpolation. Subsequently, a model is constructed based on the geometric characteristics of the broken lines to measure the degree of correlation [23].

In this study, the Grey Relational Analysis method is utilized to compute the correlation degree of each indicator in the evaluation index system for assessing the degree of coupling coordination between ecological carrying capacity and industrial development systems. Based on this, the strength of the impact of each evaluation indicator on the degree of coupling coordination within the systems is determined. Firstly, the data undergoes dimensionless processing. Then, the reference sequence (x_0) and comparison sequences (x_1, x_2, ..., x_m) are determined. The correlation coefficients between each indicator in the comparison sequences and the reference sequence are computed using Formula (1). Finally, the Grey Relational Degree is calculated using Formula (4), and the Grey Relational Degrees are sorted to draw conclusions.

$$y(x_0(k),\ x_i(k)) = \frac{a+\rho b}{\left|x_0(k)-x_i(k)\right|+\rho b},\ i=1,2,\cdots,m.\ k=1,2,\cdots,n. \tag{1}$$

$$a = \min_i \min_k \left|x_0(k)-x_i(k)\right| \tag{2}$$

$$b = \max_i \max_k \left|x_0(k)-x_i(k)\right| \tag{3}$$

$$y = (x_0, x_i) = \frac{1}{n}\sum_{k=1}^{n} y(x_0(k),\ x_i(k)) \tag{4}$$

Here, 'a' represents the minimum difference between two levels, 'b' denotes the maximum difference between two levels, and 'ρ' stands for the resolution coefficient (with ρ=0.5).

4. Calculation and Analysis of Ecological Carrying Capacity and Industrial Coordinated Development in Xilin Gol League

4.1. Analysis of Integrated Development Index for Ecological Carrying Capacity and Industrial Systems

From 2011 to 2021, the ecological carrying capacity index of Xilin Gol League exhibited a gradual upward trend with fluctuations. Specifically, the ecological carrying capacity index notably increased from 2011 to 2017. This can be primarily attributed to the initiation of national policies aimed at incentivizing grassland ecological subsidies, which facilitated the implementation of various policies in ecological protection and construction in Xilin Gol League. Since 2011, Xilin Gol League has been actively reducing desert areas and transitioning farmland to grassland, thereby enhancing overall grassland quality and promoting the restoration of grassland ecology [24]. From 2017 to 2018, the ecological carrying capacity index of Xilin Gol League decreased from 0.6359 to 0.5863, indicating a deterioration of the ecological environment and increased ecological pressure during this period. The main reason for this was the severe outbreak of pests, droughts, and extreme low-temperature weather in Xilin Gol League. The occurrence of pests and droughts had a significant negative impact on the ecological environment of the Xilin Gol grassland, while the extreme low-temperature weather caused certain damage to the grasslands in the region. From 2018 to 2019, the ecological carrying capacity index increased from 0.5863 to 0.6823, indicating a preliminary alleviation of the trend of ecological environment deterioration. However, by 2021, the ecological carrying capacity decreased to 0.6452, showing a slight negative growth. This was due to the continued presence of illegal activities damaging grasslands and forests, such as illegal discharge of pollutants leading to destruction of grasslands and forests.

From 2011 to 2021, the industrial system evaluation index of Xilin Gol League exhibited a gradual upward trend with fluctuations, increasing from 0.2894 in 2011 to 0.5673 in 2021, reflecting significant progress in the economic and social development of Xilin Gol League. Specifically, from 2012 to 2013, the industrial system evaluation index declined from 0.3886 to 0.2952. During this period, the total grain output in the region sharply decreased, with the grain output in 2013 reaching 366,500 tons.

During the period from 2011 to 2021, driven by the comprehensive promotion of ecological and industrial development systems, the overall comprehensive evaluation index of the system showed a gradual increase, rising from 0.3284 in 2011 to 0.6063 in 2021. Although there was a slight decline from 2012 to 2013, the trend has been steadily increasing since 2013, attributed to the emphasis placed by both national and local governments on the coordinated development of ecological environment and economic and social development, as well as improvements in relevant policies and regulations., see Fig. 1.

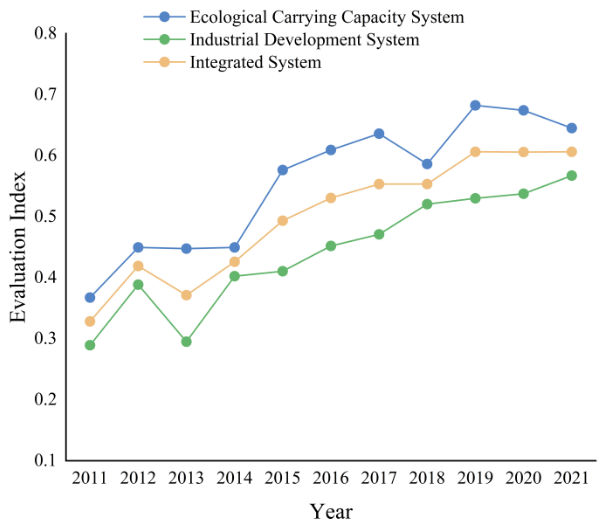

Fig. 1 System Development Evaluation Index from 2011 to 2021

4.2. Analysis of the Coupled and Coordinated Development between Ecological Carrying Capacity System and Socio-Economic System

Using a coupled coordination model, calculations were conducted to assess the coupling coordination between the ecological carrying capacity system and the industrial development system in Xilin Gol League. This evaluation aims to gauge the degree of coordination between economic and social development and ecological development in the region. As depicted in Fig.2, from 2011 to 2021, the coupling coordination exhibited a fluctuating upward trend throughout the entire study period, rising from 0.3284 in 2011 to 0.6063 in 2021. According to the assessment in Table 2, the years from 2011 to 2015 were characterized by a state of basic discoordination, as evidenced by the x-y values indicating that the ecological carrying capacity index exceeded the industrial development index. This period reflects a basic discoordination state typified by economic development lag. Although from 2016 to 2021, the overall situation shifted towards a state of basic coordination, the years 2016-2019 still saw the ecological carrying capacity index surpassing the industrial development index, indicating a basic coordination state characterized by economic development lag. However, by the period from

2020 to 2021, there was a slight improvement in the phenomenon of industrial development lag.

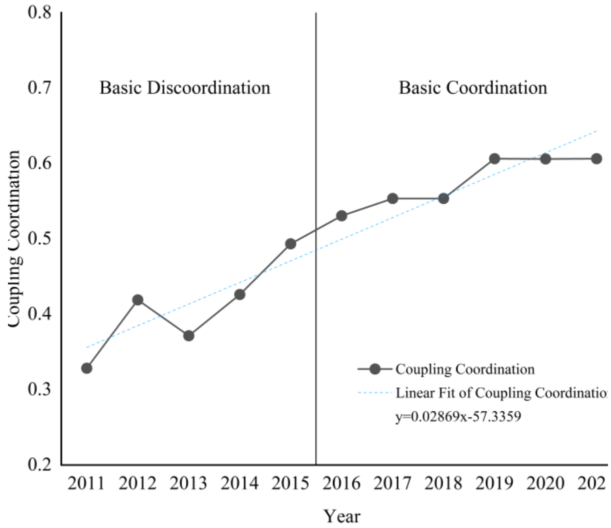

Fig. 2 Coupling Coordination between Two Systems from 2011 to 2021

4.3. Attribution Analysis

To ascertain the primary factors influencing coupling coordination, this study applied grey relational analysis to examine the relationship between coupling coordination and selected indicators. By conducting calculations on the SPSSPRO online data analysis platform, the research assessed the correlation between various indicators in the evaluation system of ecological carrying capacity and industrial development in Xilin Gol League, and the coupling coordination of the system. Using the coupling coordination results as the reference sequence and selecting the selected indicators as the reference sequence, indicators with correlation coefficients higher than the average were identified to determine the main influencing factors. The distribution of the main influencing factors is illustrated in Fig.3.

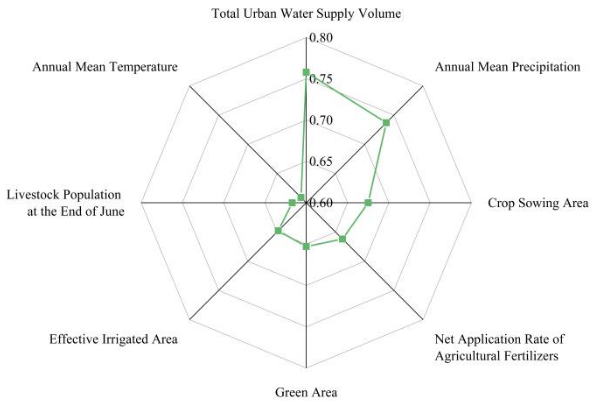

Fig. 3 Factors Influencing Coupling Coordination (Ecological Carrying Capacity System)

As shown in Fig.4, within the ecological carrying capacity subsystem, the urban water supply volume contributes the most to the degree of coupling coordination between the ecological carrying capacity and industrial development system in Xilin Gol League, with a correlation coefficient of 0.758. Following closely is the annual average precipitation, with a correlation coefficient of 0.737, and thirdly, the total sown area of crops, with a correlation coefficient of 0.675. Within the industrial development system, the total output value of agriculture, forestry, animal husbandry, and fishery, per capita GDP, and per capita disposable income of urban permanent residents are the three most significant indicators contributing to the degree of coupling coordination, with correlation coefficients of 0.758, 0.697, and 0.671, respectively.

The results of factor identification indicate that the ecological carrying capacity system indicators account for 54.27%, while the industrial development system indicators account for 45.73% in Xilin Gol League. The indicators within the ecological carrying capacity system are crucial factors influencing the degree of coupling coordination between the two systems in the region, primarily represented by urban water supply volume and regional average precipitation. The impact of indicators within the industrial development system on coupling coordination is slightly less significant compared to ecological carrying capacity, mainly driven by the total output value of agriculture, forestry, animal husbandry, and fishery. Therefore, coordinating water ecology, environmental protection, and water resource management is a critical measure at the present stage to promote the coordinated development of ecological carrying capacity and socio-economic progress in Xilin Gol League.

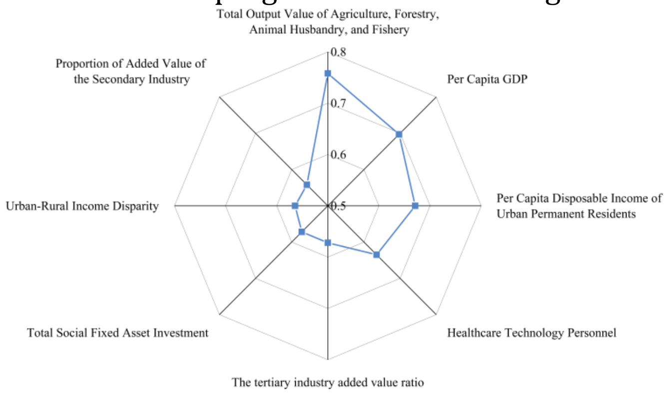

Fig. 4 Factors Influencing Coupling Coordination (Industrial Development System)

5. Conclusions and Discussions

5.1. Conclusions

In contrast to existing studies on the coordinated development of ecology and socio-economics [25-28], this article establishes an evaluation index system based on the characteristics of Xilin Gol League. It employs a coupled coordination model to analyze and evaluate the evolving trends of coupling and coordination between the ecological carrying capacity and industrial development systems from 2011 to 2021. Furthermore, the study utilizes the grey relational analysis method to assess the correlation between the ecological carrying capacity system and the industrial development system with their coupling coordination, aiming to determine the primary influencing factors. The following conclusions are drawn from the analysis:

From 2011 to 2021, the comprehensive levels of the ecological carrying capacity system and the industrial development system exhibited a fluctuating upward trend. Starting in 2019, the development pace of the ecological carrying capacity system experienced a decline, indicating a negative growth state.

From 2011 to 2021, the comprehensive coordination of the ecological carrying capacity system and the industrial development system continued to improve. Between 2011 and 2016, the level of coupled coordination was in a state of basic discoordination characterized by economic development lag. However, from 2016 to 2021, the level of coupled coordination transitioned into a state of basic coordination with economic development lag. During this period, there was a slight improvement in the phenomenon of industrial development lag, particularly noticeable between 2020 and 2021.

Between 2011 and 2021, urban water supply volume and the total output value of agriculture, forestry, animal husbandry, and fishery are the most significant factors influencing the coupling coordination between the ecological carrying capacity and industrial development systems in Xilin Gol League, followed by the annual average precipitation. There should be an emphasis on the consumption of essential water supplies to alleviate water pressure, implement the new concept of water conservation priority, explore new ideas for water conservation, and promote high-quality development of the economy, society, and ecological environment.

5.2. Discussions

Building upon the analysis of the coupling coordination between the ecological carrying capacity and industrial development systems in Xilin Gol League, this study further delved into the primary influencing factors of the coupling coordination between these two systems. By employing coupling coordination and grey relational analysis methods and constructing their respective indicator systems, the study explored the coupling coordination and influencing factors of the two systems in the region. This research provides decision-making insights for the sustainable and high-quality development of Xilin Gol League.

The results indicate that from 2011 to 2019, the ecological carrying capacity system in Xilin Gol League gradually improved (Fig.1). This improvement can be attributed primarily to the initiation of the national grassland ecological subsidy incentive policy in 2011, which propelled Xilin Gol League to implement various policies aimed at ecological conservation and construction [29,30]. These policies facilitated the restoration of grassland ecology by reducing desertification and facilitating the conversion of farmland to grassland, thereby enhancing the overall quality of grassland ecology [24]. Starting from 2019, the ecological carrying capacity index exhibited a negative growth trend, while the index for the economic development system saw rapid growth. Xilin Gol League experienced swift industrial development, yet many areas suffered from severe industrial pollution, which had significant and detrimental impacts on the ecology. Consequently, the regional ecological environment is increasingly facing serious challenges, necessitating heightened attention and action.

The coupling coordination between the ecological carrying capacity and industrial development systems in Xilin Gol League has continuously improved (Fig.2), which aligns with findings from relevant previous studies [31]. Although there was a slight decline between 2012 and 2013, the trend has been steadily rising since 2013, attributable to the increasing emphasis placed by both national and local governments on the coordinated development of ecological environment and socio-economic progress, as well as improvements in relevant policies and regulations.

This study integrates the influencing factors of both systems and identifies urban water supply volume, total output value of agriculture, forestry, animal husbandry, and fishery, as well as precipitation, as the primary influencing factors. This analysis contributes to enhancing the driving mechanisms for the ecological and socio-economic development in Xilin Gol League:

Urban water usage is a critical aspect that cannot be overlooked. With the improvement in people's living standards, the issue of water consumption for domestic purposes has not received adequate attention, leading to severe wastage of water resources [32]. Xilin Gol League is experiencing rapid industrial development, leading to increased water intake in high-energy-consuming sectors such as electricity and heat production, chemical materials and chemical products, non-ferrous metal refining and processing, and ferrous metal smelting and processing. However, the rate of water reuse is low, and there is significant room for growth in wastewater treatment capacity [33].

During the "13th Five-Year Plan" period, the overall economic output of agriculture and animal husbandry in Xilin Gol League continued to expand, with comprehensive strength steadily improving [34]. The total output value of agriculture, forestry, animal husbandry, and fishery increased from 12.876 billion yuan in 2011 to 27.376 billion yuan in 2021, marking a growth of 112.6% over the span of 11 years, with an average annual growth rate of 10.2%. The development of agriculture and animal husbandry has achieved significant results. The overall economic output of agriculture and animal husbandry has continued to expand, indicating a rising trend of economic activities in the agricultural and animal husbandry sectors.

Simultaneously, the comprehensive strength of the region has been steadily improving. This signifies not only an expansion in scale but also the continuous enhancement of strength and competitiveness in various aspects of agriculture and animal husbandry. This comprehensive enhancement lays a solid foundation for the sustainable development of this sector.

Xilin Gol League is experiencing a noticeable trend towards warmer and drier climate conditions [35,36,37], characterized by a gradual increase in temperature [38] and a significant decrease in precipitation [39,40].The changes in the natural environment serve as external driving forces for the deterioration of the ecological environment in Xilin Gol League. Within the natural environment, there is a consensus regarding the impact of climate change on ecological degradation [41,42]. This impact is evident in the influence of precipitation on the regional ecological environment, with summer precipitation exerting a particularly significant effect [18].

Acknowledgements

Special thanks to the Inner Mongolia Autonomous Region Higher Education Scientific Research Project: “Study on the Industrial Layout and Land Ecological Evaluation of Xilinguole Grassland” (NJSY21459) and High-level/Excellent Doctoral Talent Introduction Research Initiation Project at Inner Mongolia Agricultural University - “Natural Resource Survey and Land Spatial Planning” (NDYB2019-23) to providing financial support for this study.

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