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Study on the Coupling and Coordination Relationship between Gross Ecosystem Product (GEP) and Regional Economic System: A Case Study of Jiangxi Province

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Abstract: The Gross Ecosystem Product (GEP) is an important way to assess the state of the ecosystem and to clarify the coupling and coordination between the ecosystem and the economic system, which can be a scientific basis for achieving the synergistic development of economic society and ecological civilization. In this paper, 11 prefectural cities in Jiangxi Province are taken as research areas. Based on the data of land use, normalized difference vegetation index, net primary productivity, soil, meteorology, elevation and statistics, the study accounts for the GEP in Jiangxi Province in 2010 and 2020 based on a biophysical model, and analyzes the changes of its ecosystem's state. Based on the economic data obtained from the Jiangxi Statistical Yearbook, a regional economic index system was established; the levels of GEP and the regional economy were measured with the help of entropy-weight-TOPSIS method, and the interaction mechanism and coupling coordination dynamics between them were explored based on the coupling coordination degree model. It was found that during 2010–2020, the GEP in Jiangxi Province increased by 0.35%, and the value of material goods and cultural services increased by 49.57% and 414.03%, respectively, but the value of regulating services decreased by 9.89%; the main coupled and coordinated development characteristics of ecosystem and economic system in Jiangxi Province developed from basic coordination-economic lagging to moderate coordination-ecological lagging, and the coupled coordinated development continues to improve, but the development of gross ecosystem product lags behind the level of economic development.

Keywords: gross ecosystem product (GEP); regional economic; coupling coordination; Jiangxi province

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1. Introduction

In addition to creating and maintaining Earth's life support systems and forming the conditions for human survival and development, ecosystems and their ecological processes provide humans with a wealth of ecological products, including food, medicine, timber, biodiversity, and raw materials for industrial and agricultural production needed for life and production, as well as regulatory services such as water conservation, soil conservation, climate regulation, flood storage, and cultural services [1,2]. The product and service function of ecosystems is the foundation of human existence and development, and has important ecological and economic value [3]. As China's economy continues to develop at a high rate, the constraints on economic development due to resource and environmental issues have become more and more serious, and the unreasonable use of ecological resources by humans has led to the destruction of ecosystem functions and the consequent impact on the value provided by ecosystems [4,5]. Ecological value and economic value are intrinsically related [6,7]. Hence, how to measure the state and changes of the GEP, realize the sustainable use of the "golden mountain" and develop ecology and economy synergistically are the hotspots and difficulties of research in ecology and ecological economics, and are urgently needed for the construction of ecological civilization [8].

In China, the corresponding concept of ecosystem service value is GEP, which is an upgraded version of the concept, and its purpose is to better solve the application problem [9,10]. In 2013, researcher Ouyang Zhiyun and Dr. Zhu Chunquan, the then-representative of the International Union for Conservation of Nature (IUCN) in China, pioneered the concept of "gross ecosystem product" (GEP), which is defined as an ecosystem within a certain period of time (usually one year); the sum of the value of final products and services provided for human well-being, in view of the economy and society constructs the indicator system and accounting method of GEP accounting [11]. Many Chinese experts and scholars have carried out research on different ecosystem types or different regional scales on this basis [9,12–16]. In addition, Ethiopia [17], Kenya [18], Peru [19], Bangladesh [20], Australia [21], the United Kingdom [22], the United States [23,24], and other countries are also conducting research on the value of ecosystem services. At the same time, there are also evaluation studies on ecological compensation, ecological benefits, and ecological protection effects based on the accounting of the GEP [25–27]. By calculating the gross value of regional ecosystems in different times and spaces, it is possible to find out the real estate of ecological resources in the region, understand the changes in the value of regional ecosystems, and compare the size of GEP in different regions in the region. Different from GEP, GDP reflects the sum of added value created by human production activities, and does not take into account the destruction of resources and environmental pollution [10,28]. The imbalance between regional GDP and GEP is still the focus of current research. Some scholars have used different theoretical methods to study the evolution of the interaction of ecological and economic systems in different scales. Zhang et al. studied the establishment of an analytical framework to determine the stage of synergy/evolution between GEP and GDP per capita, and the regional contribution of GEP-GDP synergies [29]. In Xu et al., the Lotka-Volterra coordination degree model was established, and the mutual influencing factors and coupling coordination degree between the economic and ecological systems were analyzed using Chinese economic data from 1997 to 2016 [30]. Guan et al. used the Tapio decoupling model, the spatial autocorrelation model, and the LMDI decomposition model, and analyzed the spatiotemporal variation in gross ecosystem product (GEP) in Hubei Province, as well as the relationship between GEP and economic growth [31]. In addition, there are many studies on constructing an index system to comprehensively assess the ecological economic system [32–34], but few of them analyze the coupling and coordination relationship between the Gross Ecosystem Product (GEP) and the economic system at the provincial level.

Aiming to achieve the synergistic development of the ecosystem and the economic system, exploring the establishment of a GEP accounting system in accordance with the local ecosystem has become a feasible way to quantify the ecological value of a place and open up channels for the conversion of resources, assets and funds [29]. GEP accounting should be a decision-making tool to achieve high-quality development and an effective way to guide local actions to preserve and improve the eco-environment [35]. The analysis of the coordinated development of ecological economy from the perspective of GEP changes has practical guiding significance for enriching the GEP accounting system, promoting the realization of ecological product value, and the coordinated development of the ecological-economic system. A good ecological environment is one of the most universal benefits to people's livelihoods. In order to adhere to and improve the ecological civilization system, it is important to establish an ecosystem-based GEP accounting system, explore the driving factors of GEP changes, and form an effective local development path. This is an important direction.

The Central Committee of the Communist Party of China and State Council published "Multiple Opinions on Improving Strategies and Systems of Functional Main Zones" in October 2017, and decided to conduct pilot projects on the ecological product value realization mechanisms in Zhejiang, Jiangxi, Guizhou, and Qinghai provinces. On 23 June 2021, Jiangxi Province took the lead in promulgating the "Implementation Plan on Establishing and Improving the Value Realization Mechanism of Ecological Products". However, with the industrialization and urbanization process of Jiangxi Province, there are still unregulated and unreasonable land use and development activities, and the coordination of regional economic and ecosystem development needs to be enhanced. In recent years, how to develop the economy while protecting the environment has become an urgent problem to be solved [5,36]. Few scholars have studied the coupling and coordination relationship between GEP and regional economies. The ecological system and the economic system are the two systems that are most closely related to human survival and development [37]. Therefore, how to accurately understand their interaction mechanisms and the coordinated development and change of an ecological system and an economy is an important prerequisite for achieving the double growth of GEP and a regional economy. Based on this, this paper discusses the coupling coordination relationship between GEP and a regional economy on the basis of GEP accounting and analysis, which is helpful for promoting government performance appraisal, making the government pay attention to economic development and ecological environment protection at the same time, and also helpful for other regions in the world to measure the coupling coordination degree of GEP and regional economies. This paper takes 11 prefecture-level cities in Jiangxi Province as the research area, calculates the gross value of ecosystem production in Jiangxi Province in 2010 and 2020, and analyzes the changes in its ecosystem state; the entropy-weight-TOPSIS method measures the level of GEP and regional economy, and discusses the interaction mechanism and coupling coordination dynamic relationship between the two. Our research improves the application of GEP accounting results, and proposes a study on the coupling and coordination relationship between GEP and a regional economy. The results of the study can be an important scientific reference for the transformation of “green hills” into “golden mountains” in the path of green development.

2. Coupling and Coordination Mechanism of GEP and Regional Economy

The ecological and economic system form a dynamic change system that promotes and restricts each interest through the interaction and coupling of material flow, energy flow, and information flow relationships [38,39]. GEP is the sum of the value of the various material goods and services provided by ecosystems in a region for human and socio-economic growth, which includes the value of the material goods, the regulating services, and the cultural services provided by ecosystems [11]. There are complex interactions between ecosystems and economic systems. Economic development can provide support for ecological governance and protection, while GEP also provides support for high-quality economic development [37]. Therefore, there is a coupling and coordination relationship between the regional economy and the GEP, one in which each affects and restricts the other (Figure 1).

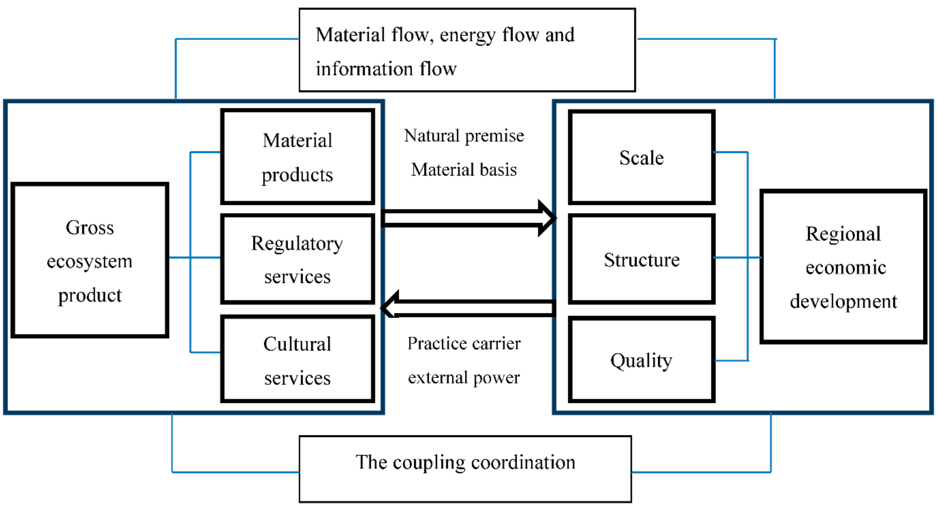

Figure 1. Coupling and coordination mechanism of GEP and regional economic development.

First, GEP provides development space and an ecological foundation for regional economic development. Regional economic development depends on the ecological value provided by the ecosystem and is affected by the GEP's own attributes. Ecosystems are the basis of human development, production and life. Humans' unreasonable development and utilization of ecosystems will cause regional economic development to pay the price of environmental damage [40]. Different types of ecosystems in the region will affect human production activities. For example, farmland and wetland ecosystems develop the primary industry economy, and urban ecosystems are mostly dominated by secondary and tertiary industries. Good ecosystems are essential for achieving population agglomeration and high-quality regional economic development. Only on the premise of the rational development of regional resources, guaranteed by the gross production value of the ecosystem, and continuously improving the overall competitiveness of the regional economy, can the ecosystem be promoted, and sustainable development of the regional economy be pursued [41]. Second, regional economic development is the practical carrier and material basis of the gross product of the ecosystem. High-quality economic development facilitates the harmonization of ecosystems and, conversely, can unbalance them [42]. The regional economic system enhances the tolerance and stability of the ecosystem by providing the human and material resources for environmental protection for the ecosystem [43]. In addition, with the acceleration of urbanization, urban ecosystems continue to crowd out other ecosystems with high GEP, and the development of the secondary industry also changes the structure of regional ecosystems. When the economy develops moderately, based on the exploration of GEP, the benign coupling and coordinated development of GEP and regional economy can be achieved [44].

For the GEP subsystem [31,45–47], the "Material products" consideration measures the various material resources obtained from the ecosystem by human beings through direct utilization or conversion without damaging the stability and integrity of the ecosystem. "Regulation services" measures the benefits provided by ecosystems in the process of life-sustaining material circulation and energy conversion to improve human living environment and living conditions, including water conservation, soil conservation, flood storage, water purification, air purification, carbon fixation, oxygen release, climate regulation, etc. "Cultural services" measures the non-material benefits brought by ecosystems and the various cultures that coexist with them, such as knowledge acquisition, relaxation and reflective contemplation. Within the regional economic subsystem [48–50], "Economic scale" measures the total social wealth, represented by per capita GDP and per capita local fiscal revenue. "Economic structure" measures the composition and structure of the national economy, represented by the proportion of secondary industry and tertiary industry; "Economic quality" measures regional economic development, represented by per capita investment in social fixed assets and per capita total retail sales of consumer goods.

3. Data Sources and Research Methods

3.1. Overview of the Study Area

Jiangxi Province, referred to as Gan, is located in the central region of China, between 24°29′ N to 30°04′ N and 113°34′ E to 118°28′ E. The two provinces of Zhejiang are connected, adjacent to Hunan in the west, Hubei and Anhui in the north, and Guangdong in the south (Figure 2). The terrain is high in the south and low in the north, with the Luoxiao Mountains on the west side, with an average elevation of more than 1 km, the Nanling Mountains in the south, the Wuyi Mountains in the east, and hills and basins in the middle, while the topography of the province slopes towards the Poyang Lake Plain in the north. The total area of Jiangxi Province is 166,900 km^2; the resident population of Jiangxi Province is 45,174,000 as of the end of 2021, and the annual GDP in 2021 is 296.97 billion RMB. The urbanization rate of the province's resident population rose from 45.7% in 2012 to 61.5% in 2021, and the area of urban built-up areas grew from 1078 km^2 to 1733 km^2. The ecosystem types in the territory are forest, scrub, grassland, wetland, farmland, town, and bare land, and the percentage of area of each ecosystem type in 2020 is 55.89%, 5.51%, 4.26%, 4.60%, 26.47%, 3.24%, and 0.01%, respectively. Jiangxi Province is relatively rich in ecotourism resources. With the rapidly developing economy and accelerated urbanization in Jiangxi Province, the pressure on land resources is increasing day by day. Therefore, in-depth research on Jiangxi Province's GEP and its spatiotemporal coupling relationship with the economy will help promote the construction of Jiangxi Province's ecological civilization; regional sustainable development has important practical significance.

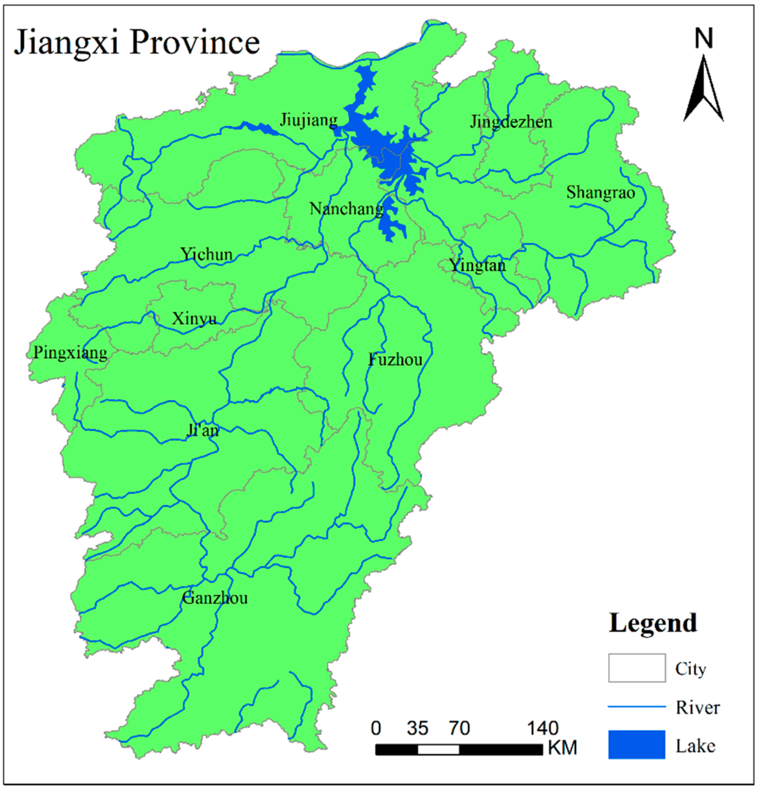

Figure 2. Geographical location of the study area.

3.2. Data Sources

The land use data used in this paper from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (https://www.resdc.cn/ (accessed on 25 April 2022)) [51]. It is based on the Landsat TM image of the US Landsat, and is generated by artificial visual interpretation. The spatial resolution is 30 m. According to the research, there are 7 types of ecosystem types in Jiangxi Province: forest, shrub, grassland, wetland, farmland, town and bare land. NDVI (Normalized Difference Vegetation Index) data were obtained from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences (https://www.resdc.cn/ (accessed on 25 April 2022)) [52] with a spatial resolution of 1000 m. NPP(Net Primary Production) data comes from the MODIS land standard product (MOD17) of the NASA website (http://www.nasa.gov/ (accessed on 25 April 2022)) [53] at a spatial resolution of 500 m. Soil data comes from the Harmonized World Soil Database (HWSD) "China Soil Dataset" with a spatial resolution of 1000 m. The meteorological data comes from the China Meteorological Data Network (http://data.cma.cn/ (accessed on 25 April 2022)) [54]; the monthly precipitation, temperature and other data of 87 stations in Jiangxi Province are obtained, and spatial interpolation is performed using the inverse distance weighting method in ArcGIS(Version:10.7.0.10450; Creator:ESRI; Location: USA), and then the raster calculator is used to process the meteorological data to obtain a raster dataset of spatial distribution of precipitation and evapotranspiration with a spatial resolution of 30 m. The DEM data of the study area comes from the geospatial data cloud (http://www.gscloud.cn/ (accessed on 25 April 2022)) [55]; the spatial resolution is 30 m. The output value of agriculture, forestry, animal husbandry and fishery products are from the "Jiangxi Statistical Yearbook" and the statistical yearbooks of various cities. The water resources consumption by industry comes from the "Jiangxi Provincial Water Resources Bulletin". The above data years are 2010 and 2020, according to the needs of the study.

There have been many research studies on the level of economic development, mainly including the single indicator method (GDP per capita) and the comprehensive indicator method [56–58]. In order to comprehensively reflect the level of regional economic development, this paper selects per capita GDP and per capita local fiscal revenue to reflect the scale of regional economic development; per capita investment of social fixed assets and per capita total retail sales of social consumer goods are selected to reflect the quality of regional economic development; the proportion of secondary industry and tertiary industry is selected to reflect the regional economic development structure. The data of the economic indicators involved come from the "Jiangxi Statistical Yearbook".

3.3. GEP Accounting

In this paper, starting from the natural geographical conditions of Jiangxi Province, the distribution characteristics of ecosystems and the services they provide, and on the basis of learning from other regional gross ecosystem product (GEP) accounting experiences [10,12–14,16,59], the indicators required for GEP accounting in Jiangxi Province include the value of material products, the value of regulation services, and the value of cultural services. Within these categories, the value of material products includes the value provided by agriculture, forestry, animal husbandry and fishery, water resources, and ecological energy; the value of regulation services includes water conservation, soil conservation, climate regulation, flood regulation and storage, carbon sequestration, oxygen release, air purification, water purification, material conservation and negative oxygen ion 10 values; the cultural service value is replaced by tourism revenue. The specific calculation formula is as follows:

$$GEP = V_p + V_r + V_c \quad (1)$$

In the formula: GEP is gross ecosystem product; V_p is the value of material products; V_r is the value of regulating service products; V_c is the value of cultural service products. The accounting methods of specific material quality and value are shown in Table 1.

Table 1. GEP accounting method.

Function Category	Accounting Subjects	Functional Quantity Accounting Method	Value Accounting Method	References
Material products	agriculture, forestry, animal husbandry and fishery products water resources eco-energy	Literature review method (Statistical yearbook, Water Resources Bulletin, Statistical Bulletin, etc.)	Market value method	[12,14,16,59]
Regulating services	water conservation	Water balance method	Shadow project method	[60,61]
	soil conservation	Revised universal soil loss equation (RUSLE)	Replacement cost method	[62–64]
	climate regulation	Evapotranspiration model	Replacement cost method	[65]
	flood regulation and storage	Water balance method and water storage equation	Shadow project method	[66]
	carbon sequestration	Mass balance method	Replacement cost method	[67,68]
	oxygen release	Mass balance method	Replacement cost method	[68]
	air purification	Plant purification model	Replacement cost method	[69]
	water purification	Water purification model	Replacement cost method	[70]
	species conservation	Survey statistics method	Opportunity cost method	[71]
	negative oxygen ions	Negative oxygen ion model	Replacement cost method	[10]
Cultural services	landscape recreation	Survey statistics method	Tourism revenue method	[10,12,14]

3.4. Construction of the Coupling Coordination Degree Model

In this paper, we first choose the entropy method, and the weight of each indicator in the economic development system is then determined by objective raw data, which comprehensively and objectively reflects the actual situation of the basic economic indicators, and effectively solves the problem of correlation between indicators [72]. In addition, this paper uses the TOPSIS method to measure the GEP and the comprehensive index of economic development, while the coupling coordination analysis provides scientific and reasonable data for it. TOPSIS is a multi-attribute decision-making method commonly used in systems engineering. The basic principle is to compute the distance of each evaluated object to the best and worst solution in order to rank the preferences [73].

The coupling coordination degree model is extensively applied to the study of coupling coordination relationships in complex systems, and has been used for coupling coordination between urbanization and ecological concerns [74], between the tourism industry, ecological concerns, and a regional economy [75], between socioeconomic and ecological environments [76]. In the study, although the coupling degree can indicate the strength of the coupling effect between the ecosystem GDP and economic development, it is difficult to reflect the synergistic effect between the two, or discuss the relationship. The coupling coordination between the two is described. The specific calculation formula is as follows:

$$D = \sqrt{C \times T} \tag{2}$$

$$C = 2\sqrt{(U_1 \cdot U_2)/(U_1 + U_2)^2} \tag{3}$$

$$T = a \cdot U_1 + b \cdot U_2 \tag{4}$$

In the formula: D is the degree of coupling coordination, D ∈ [0, 1]; the larger D is, the more coordinated the development level of the two systems is, and vice versa, the lower the degree of coordination between the two systems, the lower the value of D. C is the degree of coupling, C ∈ [0, 1]; the larger C is, the better the resonance coupling state of the two systems will be, and the smaller the C is, the less harmonious the coupling state of the two systems will be, and the state will tend to develop in a disorderly fashion. T is the comprehensive coordination index of the two systems. U_1 and U_2 are, respectively, the comprehensive index of GEP and economic development. In U1, material product value, regulating service product value and cultural service product value are selected as the evaluation indexes of GEP. In U2, we chose six economic indicators, namely, per capita GDP, per capita local fiscal revenue, per capita investment in fixed assets, per capita retail sales of consumer goods, proportion of secondary industry and proportion of tertiary industry, as the evaluation indicators of regional economic development. Then, using the above evaluation indicators, the entropy weight-TOPSIS method is used to measure the comprehensive index of GEP and economic development, respectively, and U1 and U2 are obtained; a and b are both undetermined coefficients. Since the protection of the ecosystem is equally important to the development of the economy, a = b = 0.5 is selected.

The coupling coordination model can reflect the strength of the internal relationship between GEP and economic development, but it does not reflect the differences between the two. Therefore, this paper cites the research results of Han et al. [72], and introduces the relative development model to measure the region. Whether the current state of the ecosystem is ahead or behind the general level of economic development is expressed in the formula:

$$E = U_1/U_2 \tag{5}$$

In the formula: E is the relative development degree; U_1 and U_2 are the comprehensive development level of GEP and economic development, respectively. Combined with the results of coupling coordination degree and relative development degree, and referring to the research results of grade division in the existing literature [77], the types and classification standards of the coupling and coordinated development of GEP and economic development are summarized (Table 2).

Table 2. Types and division criteria of coupling and coordinated development between GEP and economic development.

Coupling Coordination Degree	Relative Development Degree	Coupling Coordination Type	Coupling and Coordinated Development Features
0 < D ≤ 0.2	0 < E ≤ 2 2 < E ≤ 4 E > 4	Severely disordered	Severely disordered—ecological lag Severely disordered Severely disordered—economic lag
0.2 < D ≤ 0.4	0 < E ≤ 2 2 < E ≤ 4 E > 4	Moderately disordered	Moderately disordered—ecological lag Moderately disordered Moderately disordered—economic lag
0.4 < D ≤ 0.6	0 < E ≤ 2 2 < E ≤ 4 E > 4	Basic coordination	Basic coordination—ecological lag Basic coordination Basic coordination—economic lag
0.6 < D ≤ 0.8	0 < E ≤ 2 2 < E ≤ 4 E > 4	Moderate coordination	Moderate coordination—ecological lag Moderate coordination Moderate coordination—economic lag
0.8 < D ≤ 1	0 < E ≤ 2 2 < E ≤ 4 E > 4	High coordination	High coordination—ecological lag High coordination High coordination—economic lag

4. Results and Analysis

4.1. Analysis of GEP Accounting Results in Jiangxi Province

In terms of changes in the area of ecosystem types in Jiangxi Province (Table 3), forest and farmland ecosystems are the main ecosystems in Jiangxi Province. In the past 10 years, several types of ecosystem areas in Jiangxi Province have decreased, including forests, shrubs, farmland and bare land. Among them, the forest and farmland ecosystem areas had a larger net decrease, which was 959.0 km^2 and 779.8 km^2, respectively. In the past 10 years, some types of ecosystem area have increased in Jiangxi Province, including grassland, wetland, and urban areas, among which the urban ecosystem area has the largest net increase, which is 1439.5 km^2, indicating that the urbanization and industrialization of Jiangxi Province have increased significantly in the past 10 years. The reduction in the area of farmland and forest ecosystems and the increase in the area of urban ecosystems indicate that the impact of human activities on changes in ecosystem areas has been strengthened and the process of urbanization has accelerated, which will have a negative impact on GEP.

In terms of GEP (Table 4), Jiangxi Province's GEP in 2010 and 2020 was 4,640,246 million yuan and 4,656,298 million yuan, respectively (calculated at comparable prices in 2010, the same below), an increase of 0.35% from 2010 to 2020. Among the various categories of ecological products, the value of material products was 215.3 billion yuan and 322.0 billion yuan in 2010 and 2020, respectively. From 2010 to 2020, the actual increase was 106.7 billion yuan, an increase of 49.57%. In the past 10 years, Jiangxi Province has supplied ecological products. The capacity has been gradually enhanced to meet the growing material needs of the people in Jiangxi Province and surrounding areas; the value of regulating service products was 4343.1 billion yuan in 2010 and 3913.6 billion yuan in 2020, dropping by 9.89% from 2010 to 2020. The ecosystem of Jiangxi Province has brought some problems and hidden dangers, and the protection and protection methods of the ecosystem need to be strengthened and improved. The cultural service product value saw an increase of 414.03%, which is due to Jiangxi Province's active development of tourism in recent years, enriching tourism products, as shown in the table below.

Table 3. Area and change of ecosystem types in Jiangxi Province (2010–2020).

Ecosystem Type	2010 (km^2)	2020 (km^2)	Changes from 2010 to 2020	Net Change 2010–2020 (km^2)
Forests	94,280.3	93,321.3	−1.02%	−959.0
Shrubs	9264.4	9206.6	−0.62%	−57.8
Grassland	6794.0	7120.1	4.80%	326.1
Wetland	7653.9	7685.7	0.42%	31.8
Farmland	44,978.8	44,199.0	−1.73%	−779.8
Urban land	3970.0	5409.5	36.26%	1439.5
Bare land	18.0	17.3	−3.85%	−0.7

Table 4. The value and change of ecological products in Jiangxi Province (2010–2020).

Accounting Categories	2010 (Billion Yuan)	2020 (Billion Yuan)	Changes from 2010 to 2020
Material product value	215.3	322.0	49.57%
Regulating service product value	4343.1	3913.6	−9.89%
Cultural service product value	81.8	420.6	414.03%
GEP	4640.2	4656.3	0.35%

In terms of the value of material products, it can be seen from Table 5 that the value of agricultural products has increased from 80.2 billion yuan in 2010 to 131.1 billion yuan in 2020, an increase of 63.57%; the value of forest products has increased from 18.7 billion yuan in 2010 to 28.5 billion yuan in 2020, an increase of 52.73%; the value of animal husbandry products increased from 58.4 billion yuan in 2010 to 87.3 billion yuan in 2020, an increase of 49.46%; the value of fishery products increased from 25.6 billion yuan in 2010 to 36.7 billion yuan in 2020, an increase of 43.70%; the value of water resources products increased from 28.3 billion yuan in 2010 to 28.8 billion yuan in 2020, an increase of 1.82%; the value of ecological energy products increased from 4.2 billion yuan in 2010 to 9.6 billion yuan in 2020, an increase of 126.99%. The largest increase in the value of ecological energy among material products is attributed to the vigorous development of hydropower, photovoltaics and wind power in Jiangxi Province over the past 10 years. Jiangxi Province, as the country's main grain producing area, has made great progress in the output value of agriculture, forestry, animal husbandry and fishery products.

Table 5. Changes in the value of ecological material products in Jiangxi Province (2010–2020).

Accounting Categories	Product Type	Accounting Indicators (Billion Yuan)	2010	2020	Changes from 2010 to 2020
Material products	Agricultural products	Agricultural product value	80.2	131.1	63.57%
	Forestry products	Forest product value	18.7	28.5	52.73%
	Animal husbandry products	Animal husbandry product value	58.4	87.3	49.46%
	Fishery products	Fishery product value	25.6	36.7	43.70%
	Water products	Water product value	28.3	28.8	1.82%
	Eco-energy products	Eco-energy product value	4.2	9.6	126.99%

Among the regulatory service products in Jiangxi Province, it can be seen from Table 6 that the value of water conservation in 2010 and 2020 was 2076.2 billion yuan and 1744.3 billion yuan, respectively, a decrease of 15.99% in 10 years; the value of soil conservation in 2010 and 2020 was 110.1 billion yuan and 111.9 billion yuan, respectively, an increase of 1.65% in 10 years; the value of climate regulation was 1128.7 billion yuan and 1187.7 billion yuan in 2010 and 2020, an increase of 5.22% in 10 years; the value of flood regulation and storage was 820.1 billion yuan and 664.5 billion yuan in 2010 and 2020, respectively, a decrease of 18.97% in 10 years; the value of carbon sequestration was 7.5 billion yuan in 2010 and 7.4 billion yuan in 2020, a slight decrease of 0.91% in 10 years; the value of oxygen release in 2010 and 2020 was 36.2 billion yuan and 35.9 billion yuan, respectively, a decrease of 0.92%; the value of air purification was 1.078 billion yuan and 1.068 billion yuan in 2010 and 2020, a slight decrease of 0.93%; the value of water purification in 2010 and 2020 was 832 million yuan and 836 million yuan, respectively, an increase of 0.48% in 10 years; the value of species conservation in 2010 and 2020 was 154.3 billion yuan and 152.1 billion yuan, respectively, a slight decrease of 1.47%; the value of negative oxygen ions was 8.1 billion yuan in 2010 and 8.0 billion yuan in 2020, a slight decrease of 1.47%.

Table 6. The value of regulatory service products in Jiangxi Province (2010–2020).

Accounting Categories	Product Type	Accounting Indicators (Billion Yuan)	2010	2020	Changes from 2010 to 2020
Regulatory service products	Water conservation	The value of water conservation	2076.2	1744.3	−15.99%
	Soil conservation	The value of reducing sedimentation	40.89	41.5	1.65%
		The value of reducing nitrogen non-point source pollution	35.8	36.4	
		The value of reducing phosphorus nonpoint source pollution	33.4	34.0	
		total	110.1	111.9	
	Climate regulation	The value of climate regulation	1128.7	1187.7	5.22%
	Flood regulation and storage	The value of vegetation regulation and storage	656.5	482.3	−18.97%
		The value of reservoir regulation and storage	69.2	77.2	
		The value of lake regulation and storage	94.4	105.0	
		total	820.1	664.5	
	Carbon sequestration	The value of carbon sequestration	7.5	7.4	−0.91%
	Oxygen release	The value of oxygen release	36.2	35.9	−0.92%
	Air purification	The value of purified sulfur dioxide	0.515	0.511	−0.93%
		The value of nitrogen oxides purified	0.301	0.298	
		The value of cleaning industrial dust	0.262	0.259	
		total	1.078	1.068	
	Water purification	The value of purifying COD	0.592	0.594	0.48%
		The value of purifying total nitrogen	0.057	0.058	
		The value of purifying total phosphorus	0.183	0.184	
		total	0.832	0.836	
	Species conservation	The value of biodiversity	154.3	152.1	−1.47%
	Negative oxygen ions	The value of negative oxygen ions	8.1	8.0	−1.47%

In terms of the value of cultural service products (Table 7), in 2010, Jiangxi Province received 107.1 million domestic tourists, and received 79.5 billion yuan in domestic tourism revenue; in the same period, the province received 1.1 million inbound tourists, and received 346 million US dollars in foreign exchange income from tourism. Total tourism revenue was 81.8 billion yuan. In 2020, the province received 556.8 million domestic tourists, and domestic tourism revenue was 420.41 billion yuan (calculated at 2010 prices, the same below); in the same period, 130,000 inbound tourists were received, and foreign exchange income from international tourism was 29 million US dollars. The total value of landscape recreation is therefore 420.6 billion yuan. In 2020, it has increased by 414.03% compared with 2010, which is due to Jiangxi's vigorous development of tourism in the past 10 years.

Table 7. Value of cultural service products in Jiangxi Province (2010–2020).

Accounting Categories	Product Type	Accounting Indicators	2010	2020	Changes from 2010 to 2020
Cultural service products	Landscape recreation	Total number of tourists (million people)	108.2	557.0	414.78%
		Landscape and recreational value (billion yuan)	81.8	420.6	414.03%

In terms of the GEP in various cities in Jiangxi Province (Figure 3), Ganzhou was the highest in 2010 and 2020, at 851.9 billion yuan and 838.8 billion yuan, respectively; Xinyu had the lowest in 2010 and 2020, with 87.2 billion yuan and 86.4 billion yuan, respectively. The reason for the large gap in GEP between the two prefecture-level cities is the large gap in the area of the various ecosystems. The area of Ganzhou is about 12 times that of Xinyu. In Jiangxi Province, the prefecture-level city with the largest increase in the GDP in the ecosystem over the past 10 years is Jiujiang, which has increased from 591.1 billion yuan in 2010 to 695.6 billion yuan in 2020, an increase of 104.5 billion yuan. The second is Nanchang, which increased by 73.0 billion yuan, from 250.4 billion yuan in 2010 to 323.4 billion yuan in 2020. The prefecture-level city with the largest reduction in the GDP of the ecosystem is Shangrao, which decreased from 800.6 billion yuan in 2010 to 712.9 billion yuan in 2020, a decrease of 87.6 billion yuan.

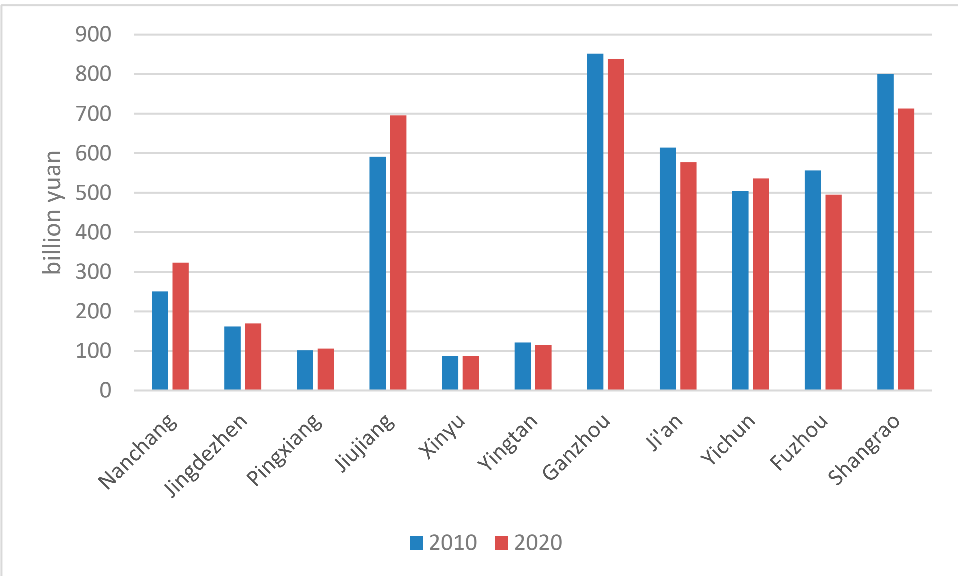

Figure 3. Gross Ecosystem Product of Cities in Jiangxi Province (2010–2020).

In terms of gross ecosystem product per unit area, this paper classified the GEP per unit area of Jiangxi Province in 2010 and 2020 by the natural breakpoint method to obtain the spatial distribution map of GEP per unit area in Jiangxi Province (Figure 4). In addition, a trend surface rendering was used to analyze Jiangxi Province. The differentiation trend of GEP per unit area is expressed across the two periods under study (Figure 5). From the east-west direction, the GEP per unit area shows an upward trend from the west to the east, and the GEP per unit area in the east is higher than that in the west. The area GEP is on the rise from south to north. The wetland ecosystem in the northern Poyang Lake area substantially contributes to GEP. Therefore, special attention should be paid to the ecological protection of the Poyang Lake wetland.

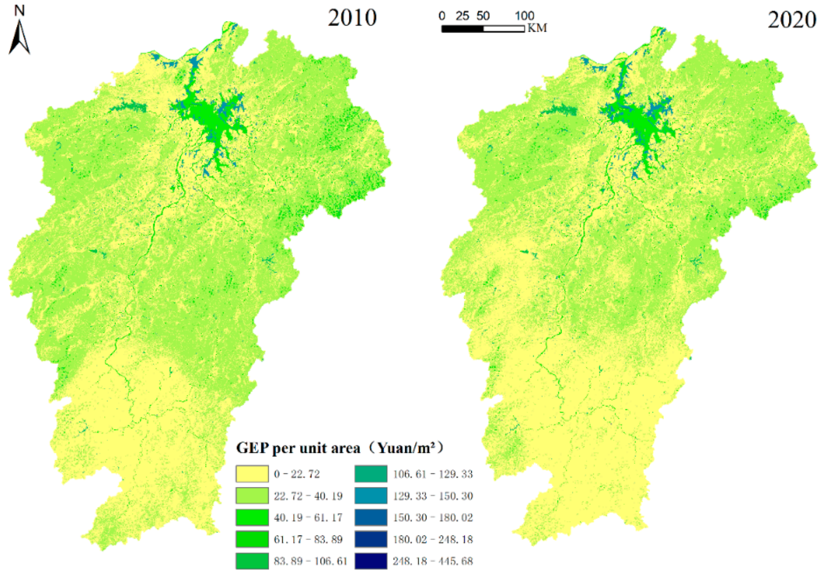

Figure 4. Spatial distribution of GEP per unit area in Jiangxi Province in 2010 and 2020.

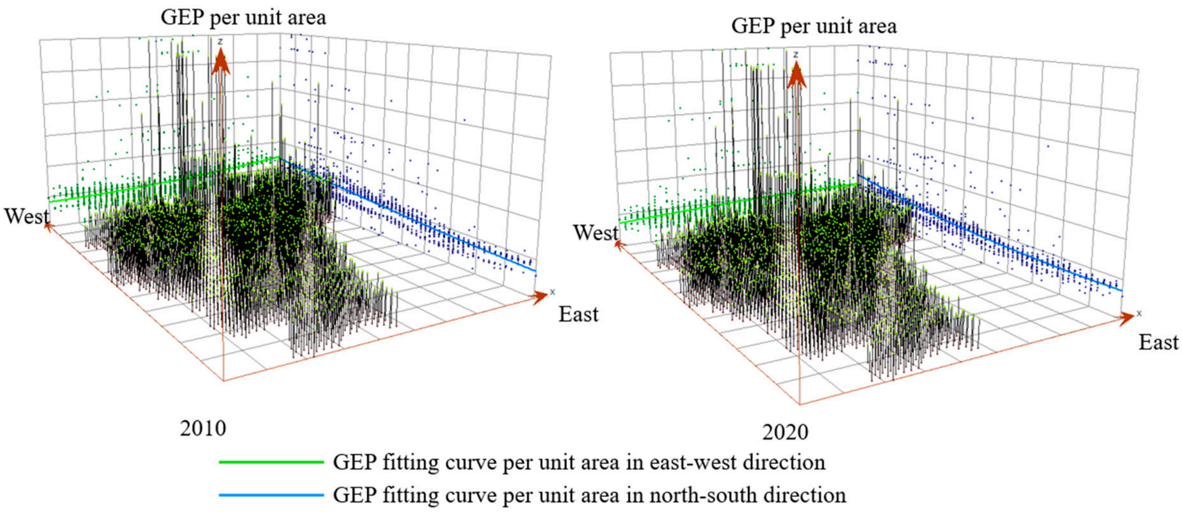

Figure 5. Evolution of GEP trend surface per unit area in Jiangxi Province in 2010 and 2020.

4.2. Spatial and Temporal Analysis of the Comprehensive Index and Coupling Coordination Degree of GEP and Economic Development

Table 8 displays the GEP composite index of various cities in Jiangxi Province: in 2010, the GEP composite index of Xinyu was the lowest, at 0.027; the GEP composite index of Ganzhou was the highest, at 0.841. In 2020, the GEP composite index of Xinyu was the lowest, at 0.002; the composite index was the highest at 0.816. The GEP composite index of Ganzhou is the highest among all the local-level cities in Jiangxi Province, because the value of material products and the value of regulating services provided by the ecosystem of Ganzhou ranks first, while the value of material products, the value of regulating services, and the value of regulating services provided by the ecosystem of Xinyu ranks first. The cultural service value is low. From 2010 to 2020, the GEP level increased the most in Nanchang, and the comprehensive index increased from 0.433 to 0.532. At this stage, the value of material products and regulating services provided by Nanchang's ecosystems did not increase very much, but its cultural service value (i.e., tourism) contributed prominently. The consumption-pulling effect is prominent; followed by Jiujiang, the composite index increased from 0.618 to 0.670. Except for Nanchang, Jiujiang and Yichun, the GEP composite index of other cities has decreased to varying degrees, which is in line with the urbanization of Jiangxi Province in the past 10 years. The acceleration of the process is not unrelated to the vigorous development of industry.

Table 8. The comprehensive index and coupling coordination calculation results of GEP and economic development in Jiangxi Province in 2010 and 2020.

City	Years	GEP	Economy	Coupling Coordination Degree	Relative Development Degree	Coupling and Coordinated Development Features
Nanchang	2010	0.433	0.714	0.746	0.606	Moderate coordination—ecological lag
	2020	0.532	0.866	0.824	0.614	High coordination—economic lag
Jingdezhen	2010	0.149	0.443	0.507	0.337	Basic coordination—economic lag
	2020	0.126	0.502	0.501	0.251	Basic coordination—economic lag
Pingxiang	2010	0.086	0.443	0.441	0.193	Basic coordination—economic lag
	2020	0.040	0.394	0.355	0.102	Moderately disordered—economic lag
Jiujiang	2010	0.618	0.260	0.633	2.381	Basic coordination
	2020	0.670	0.597	0.795	1.123	Basic coordination—economic lag
Xinyu	2010	0.027	0.766	0.378	0.035	Moderately disordered—economic lag
	2020	0.002	0.710	0.204	0.003	Moderately disordered—economic lag
Yingtan	2010	0.077	0.412	0.422	0.187	Basic coordination—economic lag
	2020	0.051	0.757	0.442	0.067	Basic coordination—economic lag
Ganzhou	2010	0.841	0.168	0.613	5.020	Moderate coordination—ecological lag
	2020	0.816	0.184	0.623	4.426	Moderate coordination—ecological lag
Ji'an	2010	0.668	0.130	0.543	5.129	Basic coordination—ecological lag
	2020	0.535	0.276	0.620	1.935	Moderate coordination—economic lag
Yichun	2010	0.605	0.132	0.531	4.592	Basic coordination—ecological lag
	2020	0.627	0.305	0.661	2.056	Moderate coordination
Fuzhou	2010	0.517	0.179	0.552	2.884	Basic coordination
	2020	0.452	0.161	0.520	2.804	Basic coordination
Shangrao	2010	0.823	0.144	0.587	5.711	Basic coordination—ecological lag
	2020	0.637	0.179	0.581	3.548	Basic coordination

From the perspective of the comprehensive economic development index, the comprehensive economic development index of various cities in Jiangxi Province can be divided into 5 categories: $0 < U_1 \leq 0.2$ indicates a very low level of economic development, $0.2 < U_1 \leq 0.4$, a low level of economic development, $0.4 < U_1 \leq 0.6$ an average level of economic development, $0.6 < U_1 \leq 0.8$ a high level of economic development, and $0.8 < U_1 \leq 1$ a very high level of economic development. In 2010, the overall economic development level of Jiangxi Province was relatively low. The economic development level of Xinyu was high, and its comprehensive economic development index was 0.766, followed by Nanchang, which had a relatively high economic development level, and its comprehensive economic development index was 0.741. The city's economic development level is not high. In 2020, the overall economic development level of Jiangxi Province had improved, and the overall economic development level was average. In the province, only Nanchang has entered a high level of economic development. From 2010 to 2020, the economic development level of Yingtan increased the most. The comprehensive economic development index increased from 0.412 in 2010 to 0.757 in 2020. The economic development level of Yingtan has improved largely, because of the copper industry chain in Yingtan. The second-highest increase was seen in Jiujiang. The comprehensive economic development index has increased from 0.260 in 2010 to 0.597 in 2020. This is attributed to the steady growth of Jiujiang's fixed asset investment, social consumption and retail sales, and local fiscal revenue over the past ten years.

According to the previously discussed coupling coordination model and relative development model, the 2010 and 2020 GEP and the comprehensive economic development index of all cities in Jiangxi Province were substituted into the calculations, and the results and changes within the coordinated development of the two were obtained.

From the perspective of the degree of coupling coordination (Table 7, Figure 6), in 2010, Nanchang had the highest coupling coordination degree, which was moderately coordinated, and Xinyu had the worst coupling coordination degree, which was moderately misaligned. In 2010, a total of seven prefecture-level cities in Jiangxi Province were in basic coordination, three prefecture-level cities were in moderate coordination, and one prefecture-level city was in moderate imbalance. In 2020, the degree of coupling coordination in Jiangxi Province was on the rise as a whole, indicating that the two systems of ecology and economy are gradually forming a positive interactive relationship. Nanchang has improved from moderate coordination to high coordination, and Yichun and Fuzhou have improved from basic coordination to moderate coordination. In 2020, a total of four prefecture-level cities in Jiangxi Province were in moderate coordination, four prefecture-level cities were in basic coordination, one prefecture-level city is in high coordination, and two prefecture-level cities were in moderate imbalance.

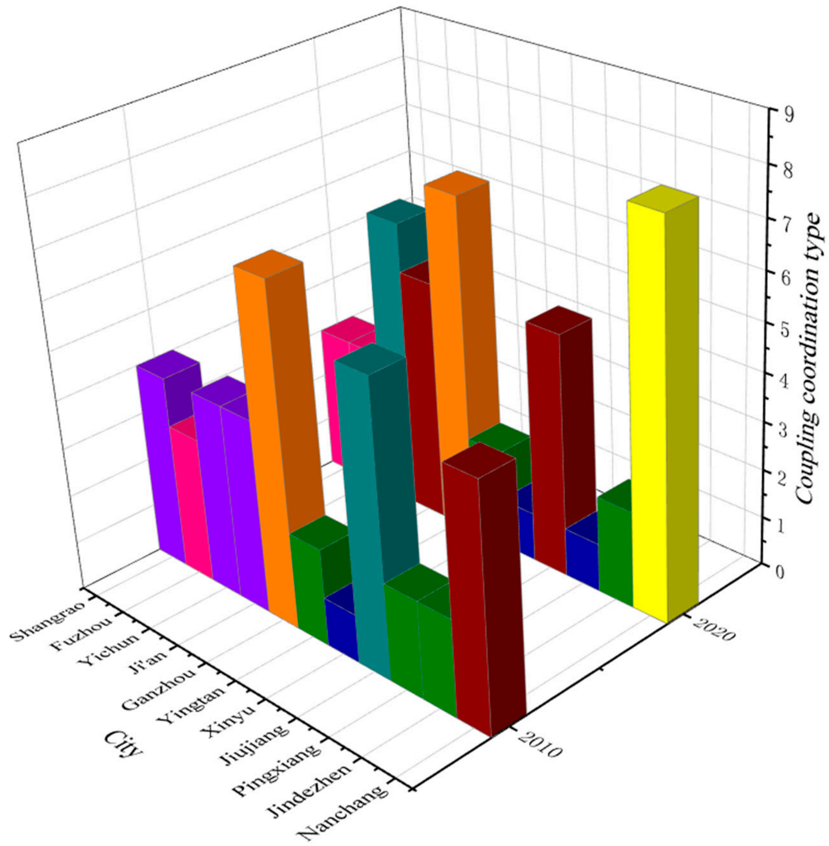

Figure 6. Changes in the degree of coordinated development of GEP and economic coupling in prefecture-level cities in Jiangxi Province in 2010 and 2020 (1: Moderately disordered—ecological lag; 2: Moderately disordered; 3: Basic coordination—ecological lag; 4: Basic coordination; 5: Basic coordination—economic lag; 6: Moderate coordination—ecological lag; 7: Moderate coordination—economic lag; 8: High coordination—ecological lag).

Considering the relative development degree, in 2010, a total of four prefecture-level cities in Jiangxi Province were in economic lag, and five prefecture-level cities were in ecological lag. In 2020, a total of seven prefecture-level cities in Jiangxi Province were in ecological lag. The main characteristics of coupled coordinated development are basic coordination-economic lag development to moderate coordination-ecological lag, which shows that Jiangxi Province's ecological system and economic system development level is more coordinated, but in the past 10 years, Jiangxi Province's economy has developed rapidly, and although the value provided by the ecosystem to human beings has improved, it is still lower than that of the economy.

5. Discussion and Suggestions

5.1. Discussion

First, the type and area of the ecosystem are very important factors in the calculation of GEP. In our accounting process, forest and wetland ecosystems tended to have higher GEP per unit area than did other ecosystem types [10,12–14,16,59]. The decrease of forest ecosystem area is the main reason for the decrease of the value of regulatory service products in Jiangxi Province. Second, among the three types of product values of GEP, the value of regulatory service products accounts for the highest proportion. In terms of the value of regulatory service products, the value of water conservation and climate regulation is higher than that of other types of regulatory service products, because the value of water conservation and climate regulation mainly comes from forest and wetland ecosystems. In terms of the value of material products, the value of agricultural products accounted for the highest. Although the area of farmland ecosystem in Jiangxi Province decreased by 1.73% in the past 10 years, the value of agricultural products increased by 63.57%, which may be attributed to the change of agricultural production mode and the increase of yield per unit area caused by the application of chemical fertilizers [78]. Thirdly, this paper analyzes the trend surface evolution of GEP per unit area in Jiangxi Province, which provides a new perspective for analyzing the spatial distribution and variation trend of GEP [79]. Fourth, China's GEP accounting uses the biophysical model method, which is more accurate than the equivalent factor method or the energy method when calculating the ecosystem services value. However, the accounting process is complex and requires high data quality. The accuracy of the data obtained in this paper will also affect the accuracy of GEP accounting; the accuracy of data acquisition should be improved in future research. Fifth, ecological products are the upgraded version of ecosystem services in China [80]. The Chinese government and scholars are leading the world in promoting the accounting use and application of GEP. The development of GEP accounting system should be a long-term process. We should fully learn from the experience and practice of the GDP accounting system development, build a perfect investigation and monitoring system, and unify accounting subjects and model methods, so as to play an important role in the field of ecological protection. Sixth, the years studied in this paper are 2010 and 2020. If the coupling and coordination relationship between GEP and regional economy in each year could be studied, the relative relationship changes between ecological and economic systems can be judged more accurately.

5.2. Suggestions for the Coordinated Development of Ecosystems and Regional Economy

5.2.1. GEP into "Assessment"

GEP can make up for the structural defects brought about by the assessment method of a single GDP indicator, and scientifically reflect the real level of development. In the new stage of development, we should give full play to the "baton" of scientific assessment, adjust assessment objectives as soon as possible, optimize assessment structure, gradually establish a dual assessment system for GEP and GDP, incorporate eco-efficiency into the economic and social assessment system, and guide the construction of a new model of green growth. It is important to research and issue the "GEP Assessment Application Management Measures" as soon as possible. The National Bureau of Statistics and relevant departments regularly conduct annual GEP assessment and assessment for local governments, and promote the establishment of a regional GEP and GDP dual assessment system to adapt to the new situation of economic restructuring.

5.2.2. GEP into "Planning"

First, the total GEP target and the total GDP target are included as prospective indicators in the outline of the national economic and social development plan, so as to ensure the coordinated and rapid growth of the total size of GDP and GEP. The conversion efficiency between them has achieved rapid growth. The second step is to carry out territorial space planning to support the transformation of "lucid waters and lush mountains are invaluable assets" pilot projects, and combine the main function positioning of each county (or city, or district), scientifically evaluate and reasonably set the ecological protection and economic development goals of each region, and realize the management and control of natural resources. The systematization, refinement and differentiation of the system provide the basic framework for various development, protection and construction activities. Third, the results of the GEP will be implemented in the spatial planning of the land and special planning for eco-restoration, so as to realize the organic connection between the use of ecological product development and the three control lines of eco-protection: red line, permanent basic agricultural land and urban development boundary, and eco-restoration.

5.2.3. GEP into "Decision"

The first step is to incorporate GEP change indicators into the comprehensive evaluation system for decision-making on major issues, appointment and dismissal of important officials, arrangement of significant projects, and the use of funds in large amounts, as important guidelines and hard constraints for decision-making. Comprehensively build a responsibility system and accountability system with the core goal of improving the eco-environmental quality and enhancing the level of green growth, scientifically assess the impact of important decisions on the sustainable supply capacity of GEP, and if the important decisions cause deterioration of the quality of the eco-environment and deterioration of eco-functions, policymakers should be held accountable according to laws and regulations. Second, GEP accounting results are used for industrial development. Through GEP accounting, we will comprehensively promote "industrial ecologicalization and ecological industrialization", actively develop eco-tourism, eco-agriculture, eco-manufacturing, eco-service and eco-high-tech industries, and promote ecosystem services. The value is transformed into economic wealth and social welfare, thus realizing the transformation from "lucid waters and lush mountains" to "gold and silver mountains". While protecting the ecological environment, the policy meets the needs of the people for a beautiful environment and a better life, and realizes the coordinated growth of GEP and GDP.

6. Conclusions

Based on the perspective of GEP accounting, combined with the land use date of Jiangxi Province and the statistical data of prefecture-level cities, etc., this paper sets forth the value provided by different ecosystem services and the GEP of prefecture-level cities, specifically, describing changes of the value provided by the ecosystem for human beings in Jiangxi Province from 2010 to 20120. At the same time, according to the economic data of the prefecture-level cities, the ecological-economic coupling coordinated development of the prefecture-level cities in the past ten years is calculated. The study came to the following conclusions:

(1) From 2010 to 2020, GEP in Jiangxi Province was on the rise. The 10-year growth rate of the value of material products and cultural service products was 49.57% and 414.03% respectively, but the value of adjusted service products decreased by 9.89% in the 10-year period. In terms of the value of material products, the product type with the largest share of value was agricultural products, and the material product type with the largest increase in the past 10 years was ecological energy products. In terms of regulation service value, water conservation and climate regulation had the highest two values, respectively. The regulation service product with the largest decline in the past 10 years was flood storage, which decreased by 18.97%, followed by water conservation, which decreased by 15.99%. Among the cities in Jiangxi

Province, Ganzhou had the highest GEP in 2010 and 2020, with 851.9 billion yuan and 838.8 billion yuan, respectively; Xinyu had the lowest in 2010 and 2020, with 87.2 billion yuan and 86.4 billion yuan, respectively. In terms of GEP distribution per unit area, GEP per unit area was higher in the east than in the west, and GEP per unit area in the north was higher than in the east.

(2) From 2010 to 2020, the main coupling and coordinated development characteristics of the ecosystem and economic system in Jiangxi Province changed from Basic coordination-economic lag to Moderate coordination-ecological lag, indicating that the type of coupling and coordination between ecosystems and economic systems is evolving in a better direction, but the constraints of ecosystems on economic development are increasing.

Our research confirmed that GEP accounting should be a decision-making tool to achieve high-quality development and an important means to guide local actions to protect and improve the ecological environment. The decline in the value of regulating service products in Jiangxi Province should be the subject of closer attention by the government. While developing the economy, the government should formulate policies to protect forest and wetland ecosystems, which have high GEP per unit area. The coupling coordination degree of GEP and the economic system can be used as an evaluation index of high-quality development of regional economy, which has practical guiding significance for promoting the realization of ecological product value within the coordinated development of an eco-economic system. In future research, the study of GEP standardized accounting and the study of GEP in economic development policy making can be strengthened.

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