Environment, Resource and Ecology Journal (2022)
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2022.060505
ISSN 2616-3756 Vol. 6 Num. 5

Study on the Coupling and Coordination of Urban Socio-Economic Development and Resources and Environment: A Case Study of Fuyang City, China

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Keywords: Fuyang city, Resources and environment, Socio-economy, Coupling coordination

Abstract: To promote the development and utilization of resources in Fuyang city and to guarantee its economic and social development, it is necessary to explore the coupled coordination of socio-economy and resources and environment. The entropy value method and coupled coordination degree model were used to analyze the coupled coordination of socio-economy and resources and environment in Fuyang city from 2016 to 2020. The results show that: (1) The overall resource and environment benefits of Fuyang city show an increasing trend from 0.185 to 0.855.The overall socio-economic benefits show an increasing trend from 0.02 to 0.389. (2) The coupling degree of socio-economic development and resource and environment of Fuyang city grows from 0.382 to 0.499, the coupling coordination degree grows from 0.207 to 0.637, the coordination level from 3 to 7, achieving the growth from the level of moderate disorder to the level of primary coordination, indicating that the degree of interaction between the resource system and the economic system has been strengthening. (3) The type of coupling coordination degree in Fuyang city belongs to the economically backward type in 2016, 2018 and 2020, and the environmentally backward type in 2017 and 2019, suggesting that on the basis of resource and environmental protection, attention should be paid to socio-economic development.

1. Introduction

Fuyang is one of the major cities in northern Anhui Province, China. In recent years, Fuyang has taken the “integration of the Yangtze River Delta” and the “rise of central China” as opportunities to carry out a number of new economic development plans throughout the city, and its economy has been developing rapidly. However, the rapid economic development has brought great pressure on the resources, environment and ecosystem of Fuyang city. In particular, as the most populous city in Anhui Province, the resource and environmental carrying capacity of Fuyang is related to the healthy development of economy and society, so it is of great theoretical and practical significance to conduct a coupled and coordinated study of resource, environment and socio-economic development in Fuyang City, which is important for the improvement of economic growth, environmental protection

and resource carrying capacity of Fuyang City.

At present, domestic scholars have conducted more in-depth research on the coordination relationship between resources, environment and economic development, and fruitful research results have been achieved. For example, Xia Jing et al. of Jilin University, applied the hierarchical analysis method to quantitative analysis on the basis of qualitative analysis, so as to derive the weights of each index, and used the coupled coordination degree model to comprehensively evaluate the level of coordinated development of resources, environment and economy and society in Siping City, so as to put forward the opinion that the level of urban sewage treatment should be improved [1]. Zhang Ka et al. of Liaoning Normal University analyzed the development level of socio-economic, water resources and land resources by establishing comprehensive indicators, and established the response function of water and land resources consumption in the process of economic development in Liaoning Province, and analyzed the evolution of water and land resources system in Liaoning Province from 2011 to 2012, thus suggesting that Liaoning Province should accelerate the adjustment of industrial structure in the future, etc.[2]. Su Shengliang et al. applied a combination of entropy power method and coupled coordination degree model combined with geographic probe to analyze the spatial and temporal changes of ecological and economic development in the special hardship area of Ningxia Liupanshan region from 2006 to 2016, and concluded that farmers' income level and ecological environment quality are the main factors affecting the coordinated development of ecological environment and regional economy [3]. Zhao Juhua of Guangxi Normal College, taking Guangxi Province as an example, used a combination of principal component and factor analysis to comprehensively assess the population, ecological environment, and economic system, and constructed a model to evaluate their coordinated development levels in turn, through the method of fuzzy mathematics [4]. Hou Zengzhou used the coordination degree econometric model to explore the coordination relationship between socio-economic and ecological environment in Dongying City [5]. Gao Zeyang et al. used the entropy weight method and TOPSIS model thus deriving the comprehensive development index, and established the evaluation index system of economic, social, resource and environmental systems in Hexi region and conducted spatial evolutionary analysis [6]. Foreign scholars have also conducted a lot of researches in the field of coordinated development, such as using multi-objective models and system dynamics methods [7]. In terms of selecting indicators, based on the basic principles of scientificity, representativeness and validity, a system of indicators for assessing the state of resources, environment and socio-economy has been established to evaluate the coordination between the two in all aspects [8].

Based on the existing research results, this paper establishes a coupled and coordinated evaluation system of resource environment and economic development in Fuyang city, taking into account the actual situation of Fuyang city. In order to better evaluate the coordinated development of resources, environment and economy and society in Fuyang city, this paper adopts entropy value method and coupled coordination degree model in order to ensure the rapid development of Fuyang city's economy, reduce the pressure on the environment, take the road of harmonious coexistence between human and nature, and provide theoretical basis for the sustainable development of resources, environment and economy and society in Fuyang city.

2. Overview of the Study Area

Fuyang, located in northern Anhui Province, is at the southern end of the Yellow Huaihai Plain and the western side of the Huabei Plain. The whole area is a plain terrain, with undulating terrain characterized by a high northwest and low southeast, with a slight incline from northwest to southeast. Fuyang is located in the southern part of the warm temperate zone, a warm, semi-humid monsoon region. The four seasons are distinct, warm as spring, and the precipitation is suitable. Its climate is

characterized by a gradual change from the warm temperate zone to the northern subtropics. Light conditions are better than those in the south, and water resources are better than those in the north. Fuyang is a typical monsoon region, and its wind direction has significant changes during the year. Easterly winds dominate throughout the year, with the most winds coming from the northwest in winter and southerly winds dominating in summer. The sources of water in Fuyang City include mainly atmospheric precipitation, river transit water, and groundwater, with an average annual precipitation of 820-950 mm. All rivers in Fuyang City belong to the Huaihe River basin, and most of them originate in the plains south of the Yellow River, which are of the primitive rain slope type, and their water sources are mainly recharged by natural precipitation from the plains. Mineral resources are very rich and in large reserves, such as coal, iron ore and limestone mines. At present, Fuyang has 3 districts, 4 counties and 1 city, with a total area of 10,118.17 square kilometers. By the end of 2020, the urbanization rate of Fuyang is 41.97%, with a resident population of 8.2 million, and the three industrial structures account for about 14%, 37% and 49%. The leading industry is the tertiary industry, among which the emerging market is developing at a fast pace and the high-tech industry is deepening its role in promoting the economic development of Fuyang City. By the end of 2021, Fuyang City achieved a gross domestic product of 307.15 billion yuan, with a growth rate of 9.0%, ranking fourth in Anhui.

3. Research Methods and Data Sources

3.1. Indicator Selection and Data Sources

According to the basic principles of scientificity, systematicity, simplicity, representativeness and validity, and taking into account the actual situation of Fuyang City, a total of 12 indicators were selected to establish a coupled coordination degree evaluation index system with the level of resource and environment development and the level of economic development of Fuyang City as the guideline layer (see Table 1), and the attributes of each indicator were determined. It includes socio-economic data and resource and environmental data. The data selected in this paper were obtained from the 2017-2021 Fuyang Statistical Yearbook and the 2017-2021 Anhui Statistical Yearbook.

3.2. Determination of Indicator Weights

3.2.1. Data Standardization

Since the attributes and characteristics of the 12 selected indicators are different and their respective units of quantity are inconsistent, direct comparisons cannot be made, so the 12 indicators need to be standardized so that the weights obtained will be more objective, and the polar difference method is used here[9] . The calculation formula is as follows.

$$\text{Positive indicators: } Y_{ij} = \frac{X_{ij} - X_{j\,\min}}{X_{j\,\max} - X_{j\,\min}} \tag{1}$$

$$\text{Negative indicators: } Y_{ij} = \frac{X_{j\,\max} - X_{ij}}{X_{j\,\max} - X_{j\,\min}} \tag{2}$$

Where: Y_{ij} is the standardized value of the selected evaluation indicator; x_{ij} is the initial value of the selected indicator; among the j indicators, x_{jmax} , x_{jmin} are the maximum and minimum values of each indicator, respectively.Note: Positive indicators represent those that are conducive to the forward development of the economy, society and resources, and the larger the value, the more beneficial it is.Negative indicators represent those that are detrimental to economic, social and resource-based

environmental development, and the smaller the value, the more beneficial.

3.2.2. Entropy Method for Determining Indicator Weights

The entropy method is based on the amount of information available for each indicator to determine its weight, its accuracy and objectivity is better than the subjective assignment method [10]. The specific calculation process is as follows.

Calculate the weight p of the indicator value of the ith item under the jth indicator$_{ij}$:

$$P_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \tag{3}$$

Calculate the weight of the jth indicator e_{ij}:

$$e_{ij} = -k\sum_{i=1}^{m} p_{ij} \cdot \ln p_0 \tag{4}$$

Of which, $k = \frac{1}{\ln m}$

Calculate the weight W for the jth indicator$_j$:

$$W_j = \frac{1-e_j}{\sum_{j=1}^{n}(1-e_j)} \tag{5}$$

Where, Y_{ij} is the standardized value of the selected evaluation indicator; e_j represents the entropy value sought for the jth indicator; W_j represents the weight value sought for the jth indicator.

Table 1: Evaluation index system and weights in Fuyang City

normative level	metric layer	unit	Indicator attributes	weights
Level of economic and social development	GDP	ten thousand yuan	+	0.145
	GDP per capita	yuan	+	0.144
	financial revenue	ten thousand yuan	+	0.123
	Per capita disposable income of urban residents	yuan	+	0.149
	Disposable income per rural inhabitant	yuan	+	0.157
	Registered urban unemployment rate	%	-	0.113
	Engel's coefficient for urban residents	%	-	0.169
Integrated level of resource environment	Water resources per capita	m^3/person	+	0.118
	Urban sewage treatment rate	%	+	0.128
	Sulphur dioxide concentration	μg/m^3	-	0.125
	PM10 concentration	μg/m^3	-	0.123
	Green coverage of built-up areas	%	+	0.183
	Quantity of household waste treated in a non-polluting manner	ten thousand tons	+	0.135
	Green space per capita	m^2/person	+	0.188

3.3 Coupling Coordination Model

The coupling coordination degree of resource environment and socio-economy in Fuyang city is the degree of coordination between the subsystems, which is used to measure the sustainable and healthy development of economic development and resource environment. [11]. Based on the relevant literature [12], the coupling coordination degree model is used to explore and analyze the coupling coordination degree of the two subsystems of resource, environment and social economy in Fuyang City, which is calculated as follows.

$$D = \sqrt{C \times T} \tag{6}$$

$$T = \alpha f(x) + \beta g(y) \tag{7}$$

$$C = \left\{ \frac{f(x) \times g(y)}{\left[f(x) + g(y) \right]^2} \right\}^{\frac{1}{2}} \tag{8}$$

$$f(x) = \sum_{j=1}^{n} w_j X_j, \; g(y) = \sum_{j=1}^{m} w_j Y_j \tag{9}$$

Where: f(x) and g(y) are the functions of comprehensive evaluation of resource environment and economic development; T is the value of comprehensive evaluation of the two subsystems of resource environment and economic development; α and β denote the coefficients to be determined for the mutual influence of the two subsystems. From the perspective that the protection of ecological environment and economic development are equally important, both α and β take the value of 0.5; D denotes the coupling coordination index of resource environment and economic development in Fuyang city; C denotes the coupling index, and the range of C is between 0 and 1. If C=0, it means that the coupling degree between the two systems is the minimum value and the development of the two is not coordinated; if C=1, it means that the two subsystems are in a benign and orderly coordinated development state.

According to Li Guozhu's classification method [13] , and taking into account the actual situation of Fuyang City, the coupling coordination level between resources, environment and economy and society was divided into 10 levels (see Table 2 for details).

Table 2: Evaluation criteria and classification of the degree of coupling coordination

Coupling coordination D	standardized	Coupling coordination D	standardized
0 to 0.09	extreme disorder	0.50 to 0.59	barely coordinated
0.10 to 0.19	serious disorder	0.60 to 0.69	Primary coordination
0.20 to 0.29	moderate disorder	0.70 to 0.79	Intermediate coordination
0.30 to 0.39	mild disorder	0.80 to 0.89	good coordination
0.40 to 0.49	on the verge of disorder	0.90 to 1.00	Quality coordination

4. Results and Discussion

4.1. Analysis of the Evolution of the Resource-Environment System in Fuyang City

The benefit function f(x) of each resource and environment indicator in Fuyang City from 2016-2020 is calculated by equation (9), as shown in Figure 1. The results show that the resource and

environment benefit of Fuyang City is 0.185 in 2016 and 0.855 in 2020, showing an overall upward trend with an increase of about 362%. Among them, the steady increase in resource and environmental system benefits during 2016-2018 is mainly related to factors such as the government paying more attention to the protection of the environment and strengthening the comprehensive management of the environment. During this period, the urban wastewater treatment rate increased from 94.09% to 98.67%, and the amount of domestic waste treated in a pollution-free manner increased from 654,000 tons to 869,000 tons. The greening coverage of the built-up area rose from 32.7% to 36.7%. In addition to this, the relative decrease in pollutant emission concentrations was also the main reason for the increase in resource and environmental benefits, for example, the concentration of sulphur dioxide in the atmosphere decreased from 20 μg/m^3 to 9 μg/m^3. The relative decrease in resource and environmental benefits in 2019 was mainly due to a 2.36% decrease in the urban wastewater treatment rate compared to 2018, while the amount of household waste treated in a non-polluting manner decreased by 105,000 tons to 746,000 tons compared to 869,000 tons in 2018. Per capita park green space also decreased by about 1.35 square meters compared to 2018. In 2020, however, the resource and environmental benefits began to rise again, indicating a significant improvement in the ecological environment, which is closely related to the increased awareness of environmental protection. This is mainly because the urban sewage treatment rate has increased by 1.52%, the greening coverage of built-up areas has increased by 0.1% compared to 2019, and the amount of household waste treated in a pollution-free manner has reached 791,000 tons, an increase of 45,000 tons compared to 2019, while the PM10 concentration in the atmosphere has decreased to 76 μg/m^3 compared to 2019. At the same time, due to the epidemic, many industrial enterprises ceased production in early 2020, emitting relatively less sludge wastewater emissions, which protected the environment to some extent. Therefore the resource and environmental benefits in 2020 turn out to be better.

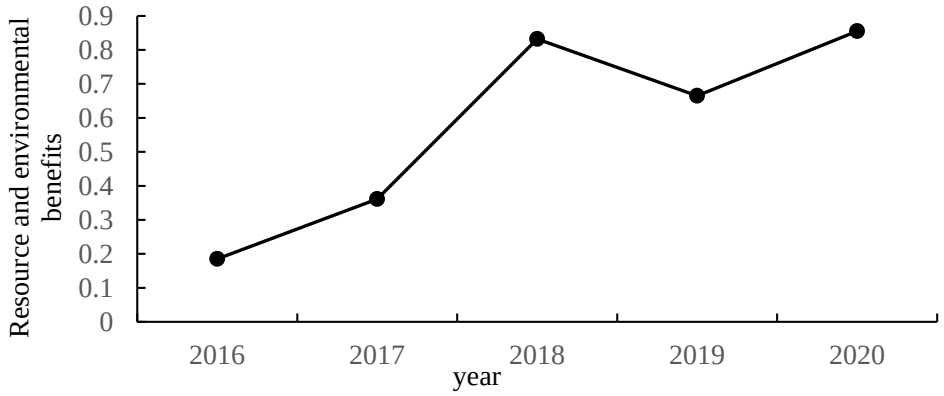

Figure 1: Trend of the resource and environmental efficiency function f(x)

4.2. Analysis of the Evolution of the Economic Development System in Fuyang

The benefit function g(y) of various economic and social indicators of Fuyang city from 2016-2020 is calculated by equation (9), which is shown in Figure 2.The results show that the economic and social benefits of Fuyang city are 0.02 in 2016 and 0.389 in 2020.The overall trend is up, with an increase of about 1845%.The economic and social benefits are steadily increasing between 2016 and 2019, where , the city's gross domestic product and gross domestic product per capita rose from 18,873,500,000 yuan and 23,982,000 yuan in 2016 to 26,860,463,000 yuan and 33,161,000 yuan in 2019, respectively. Fiscal revenue also grew to 352,306,300,000 yuan in 2019, an increase of about 126,267,500,000 yuan compared to 2016. In terms of per capita disposable income of urban residents

and rural residents, both increased from 25,483 yuan and 9,776 yuan in 2016 to 32,844 yuan and 13,079 yuan in 2019, respectively. This reflects that the economy of Fuyang City has achieved stable and healthy development, the people's livelihood has continued to improve, and the people's living standard has been significantly enhanced. In addition, the urban registered unemployment rate and the Engel coefficient of urban residents in 2016 were 2.7% and 32.4% respectively, while both dropped to 2% and 31.4% in 2019, a decrease of about 0.7% and 1% respectively, thanks to the improvement in economic efficiency. However, economic efficiency decreases in 2020, where the registered urban unemployment rate reaches 2.3%, up 0.1% compared to 2019, and the Engel coefficient of urban residents rises to 32.7%, 1.3% higher than in 2019. The slight increase in the unemployment rate was mainly due to the adverse effects of the epidemic. The rise in the Engel's coefficient also indicates a decline in the living standards of urban residents due to the impact of the epidemic.

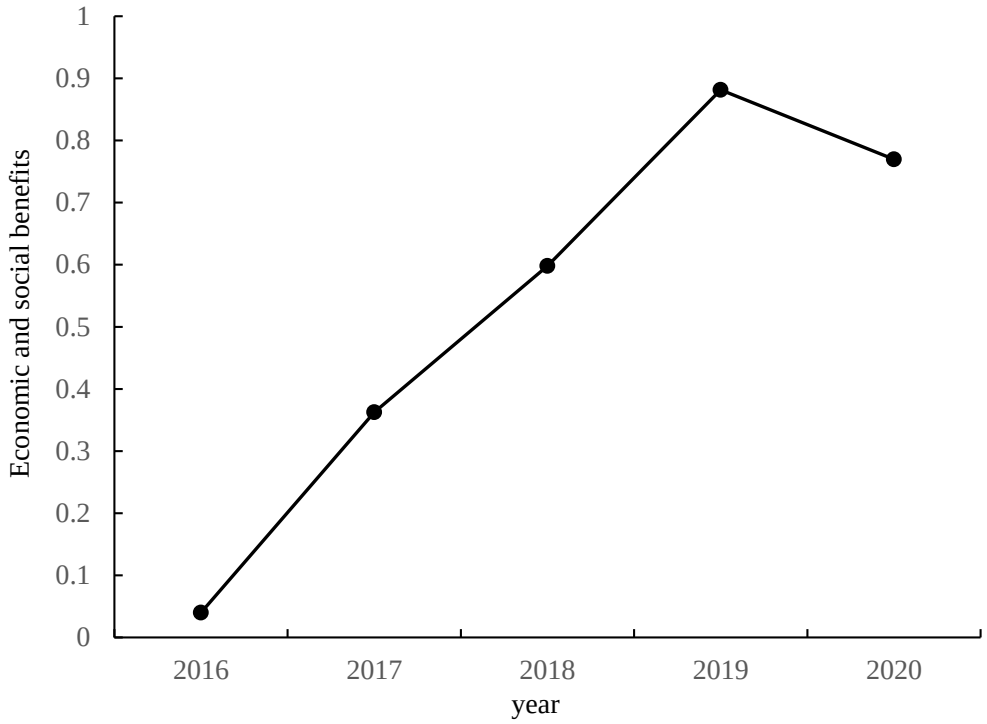

Figure 2: Trend of economic and social benefit function g(y) in Fuyang City

4.3. Evaluation of the Degree of Coordination Between Resource Environment and Economic and Social Coupling

Based on equations (6)(7)(8), the coupling degree and coupling coordination degree between resources, environment and economy and society in Fuyang City are calculated, and the specific results are shown in Table 3 and Figure 3.

The results show that Fuyang City's coupling and coordination degree between its resources, environment and economy and society always maintains an increasing trend during the period of 2016-2020, and overall its index is constantly improving. The coupling degree, on the other hand, shows a trend of increasing, then decreasing and then increasing, but the overall coupling degree has increased. The coupling degree and coupling coordination degree increase from 0.382 and 0.207 in 2016 to 0.499 and 0.637 in 2020, respectively, where the coupling coordination degree grows faster from 2016 to 2018 and slows down from 2018 to 2020. While coupling grew faster in 2017, coupling decreased in 2018, and coupling increased slightly again in 2019-2020. The coordination level, on

the other hand, changes from a moderate dissonance level in 2016 to a primary coordination level in 2020, which indicates that the degree of interaction, interpenetration and interaction between the resource system and the economic system in Fuyang City has steadily increased, and the degree of internal coordination has been further improved.

Comparing the resource efficiency function in Figure 1 with the economic and social efficiency function in Figure 2, the different years can be classified into three types: economically backward, economically and environmentally coordinated and environmentally backward. [13]. Among them, if the resource and environmental benefits are greater than the economic and social benefits, it is the economically backward type; if the resource and environmental benefits are less than the social benefits, it is the environmentally backward type; if the two benefits are equal, it is the resource and environmental coordination type. Specifically, see Table 4. The results show that among the years 2016 to 2020, 2017 and 2019 are environmentally backward type, indicating that the protection of the environment in these two years slightly lags behind the speed of economic and social development. And 2016, 2018 and 2020 are economic lagging type, which indicates that the economic development in these three years also focuses on the protection of ecological environment.

Table 3: Coupled coordination in 2016-2020

item	Coupling degree C value	Coordination index T value	Coupling coordination value	Coordination Dlevel	standardized
2016	0.382	0.113	0.207	3	moderate disorder
2017	0.500	0.362	0.425	5	on the verge of disorder
2018	0.493	0.715	0.594	6	barely coordinated
2019	0.495	0.773	0.619	7	Primary coordination
2020	0.499	0.812	0.637	7	Primary coordination

Table 4: f(x) and g(y) by year

year	2016	2017	2018	2019	2020
f(x)	0.185	0.361	0.832	0.665	0.855
g(y)	0.04	0.363	0.598	0.881	0.770
types	economically backward	Environmentally backward	economically backward	Environmentally backward	economically backward

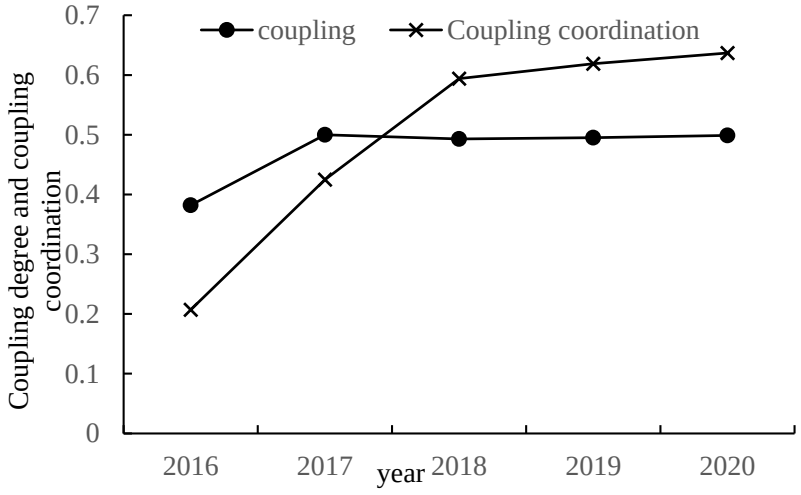

Figure 3: Coupling degree and coupling coordination

4.4. Evaluation of the Level of Coupling and Coordination

As can be seen from Table 3, the coupling coordination level between resources, environment and economy and society in Fuyang City in 2016-2020 is upgraded from moderate disorder to primary coordination. The reason for this is mainly that Fuyang City has started and gradually strengthened the protection of ecological environment while developing its economy. In the development of industry, the government attaches great importance to the environmental impact assessment of construction projects and implements a strict approval system for industries with high pollution and energy consumption, which has led to an effective reduction in the concentration of pollutants in the atmosphere. The concentration of PM10 has dropped from 88 μg/m^3 in 2016 to 76 μg/m^3 in 2020. Sulphur dioxide concentrations have also fallen from 20 μg/m^3 in 2016 to 7 μg/m^3 in 2020, a reduction of about 65% in its concentration. In addition to this, solid waste pollution is a serious threat to the city's environment and the health of its inhabitants, so the amount of household waste treated in a non-polluting manner has increased significantly during 2016-2020, from 654,000 tons in 2016 to 791,000 tons in 2020, significantly reducing solid waste pollution. In terms of water resources, per capita water resources increased from 489.5 m^3/person in 2016 to 565.04 m^3/person in 2020, and the urban wastewater treatment rate also increased from 94.09% to 97.83%. This indicates that the efficiency of water resources utilization has been improved. Fuyang City is a dry city, water resources are relatively abundant compared to the north, but compared to the south, water resources are still scarce, so the effective use of water resources and the establishment of a sound sewage treatment mechanism are conducive to the sustainable and healthy development of the environmental system of water resources. In terms of greening, the greening coverage of the built-up area has been showing a steady increase, and the green area per capita has also increased from 13.95 square meters to 17.73 square meters. Green parks and artificial forests in cities can play a role in cutting noise, smoking and dust removal, and improving the environment. Therefore, increasing the green coverage of built-up areas is not only conducive to protecting the natural ecosystem, but also to maintaining the stable operation of the urban artificial ecosystem. Meanwhile, the rapid development of high-tech industry in Fuyang City in recent years has driven the economic development, making the per capita GDP increase to 34,399 yuan in 2020, an increase of 10,417 yuan from 2016. Meanwhile, the per capita disposable income of urban residents and rural residents increased from 25,483 yuan and 9,776 yuan in 2016 to 34,562 yuan and 14,256 yuan in 2020, respectively. It shows that the living standard of the citizens has been greatly improved.

For all these reasons, the resources and environment in Fuyang City have been effectively protected and the coupling and coordination between economic development and ecological protection have increased significantly, realizing the coordination between economic development and ecological protection.

5. Conclusions

(1) The coupling coordination degree of resources, environment and economy and society in Fuyang City from 2016 to 2020 shows a continuous increasing trend, while the coupling degree shows a trend of first increasing, then decreasing slightly and then increasing again. Overall, both the coupling degree and coupling coordination index are increasing, and the coupling coordination grade is improving.

(2) As can be seen from the temporal changes in resource and environmental benefits, Fuyang City's resource and environmental benefits show a trend of increasing, then decreasing and then increasing from 2016 to 2020, but overall its resource and environmental benefits are improving. It indicates that the ecological and environmental quality of Fuyang City has improved, and the resource system has been developed sustainably.

(3) From the time change of economic and social benefits, it can be seen that the economic and social benefits of Fuyang City from 2016 to 2020 show a trend of increasing and then decreasing, which has been steadily increasing from 2016 to 2019 and decreasing in 2020, but the value of its economic and social benefits is generally increasing in 2020 compared with 2016. It indicates that the economic development level of Fuyang City has improved in recent years.

Acknowledgments

This project was funded by key project of humanities and social sciences of Anhui Provincial Department of Education (SK2020A0528); quality project of Anhui Provincial Department of Education (2020szsfkc1024); quality project of Suzhou College (szxy2021ccjy01, szxy2020xskc04); innovation and entrepreneurship training project for college students of Suzhou College Program Project (KYLXYBXM22-027); Key Scientific Research Project of Suzhou College (2017yzd13).

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