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Calculation of ecological compensation standard in a small watershed—Based on the ecological service function value method

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ABSTRACT

Small watershed ecological compensation is an important economic means to solve the contradiction between protecting the ecological environment and developing the economy. Taking the Changtian small watershed in the Xixiu District of Anshun City as an example, this paper uses the ecological service function value method to roughly calculate the ecological service function value of the small watershed ecosystem: the ecological service function value of the Changtian small watershed is 913.586 million yuan, and the total amount of ecological compensation is 11.6245 million yuan, of which the farmland system compensation is 1.3194 million yuan, the forest system compensation is 7.5336 million yuan, and the water system compensation is 256,000 yuan, The compensation for the fruit forest system is 2,515,500 yuan. Based on the value of ecosystem service function, the compensated and non-compensated ecosystem service functions are distinguished, and the equivalent factors that different ecosystems can provide compensated ecosystem functions are expressed, so that the determination of ecological compensation amount is scientific and more accurate, and then provides a basis for the determination of ecological compensation standard of the small watershed.

Keywords: Changtian Small Watershed; Ecological Compensation; Ecological Service Function Value Method; Equivalence Factor

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1. Introduction

Ecological compensation is a common means to coordinate the contradiction between economic development and ecological protection. It uses economic means to stimulate and convert the externality and nonmarket value of the ecosystem into monetary value, so as to better measure the external value of the ecosystem, and protect the ecosystem more effectively. It is an economic means that can effectively coordinate the contradiction between economic development and ecological environment protection in the region, it is also a macro means that can adjust the relationship between interests in different sections of the whole basin[1]. Ecological compensation involves key areas such as nature reserves, important ecological function areas, watershed water ecosystems, and resource development areas[2]. In ecological compensation, the ecological compensation standard is its core issue, and it is also one of the focus issues of current research in this field. At present, there are three main ways of compensation for the ecological compensation of small watersheds: social-ecological compensation, economic value ecological compensation, and natural compensation. Among them

social-ecological compensation is mainly to determine the compensation willingness of the compensation subject, including the acceptable maximum and minimum willingness to pay; economic value ecological compensation is a way to calculate the value of ecological services that can be provided by the small watershed ecosystem, so as to further determine the standard of ecological compensation; natural compensation is a way to determine the compensation standard after calculating the input cost.

In academic circles, the estimation methods of small watershed ecological compensation standards are widely used, such as the ecological service value method, conditional value method (CVM), opportunity cost method, etc. The externality theory in environmental economics clearly states that when the external marginal cost is equal to the external benefit, the environmental benefit can be maximized. Therefore, theoretically, the ecological value provided by the ecosystem can be used as the upper limit of ecological compensation[3]. Zhang Leqin and Rong Huifang[4] in their research on the ecological compensation value of the Qiupu River Basin, using the ecological service value method, took the ecological service function value of the ecosystem as the upper limit of the ecological compensation amount of the Qiupu river small watershed, which provided a reference for the ecological compensation value of the small watershed, but their research ignored the scope of benefits involved in the service function provided by the ecosystem, At the same time, it ignores whether the ecological service function provided by the ecosystem can increase the ecological marginal utility, which leads to a new problem: not all the ecological service function value provided by the ecosystem can be compensated in the basin. On the other hand, for the issue of opportunity cost, academia believes that opportunity cost is "the income given up when making a decision without making another decision". In the application of ecological compensation, opportunity cost is the economic income and development cost given up to protect the ecological environment, which can generally be used as the lower limit of the amount of ecological compensation[5]. From the perspective of opportunity cost, the conditional value method is widely used in the study of ecological compensation standards. This method was first proposed in 1947[3] and was first applied by economist Davis in 1963 when studying the recreational value of forest land in the United States[6]. Many economists in developing countries believe that this method is feasible[7]. The conditional value method simplifies the costs and expectations of the beneficiaries and the victims of ecological interests related to ecological compensation into wishes, and then visits and investigates the compensators or recipients in the form of questionnaires or interviews to obtain the corresponding willingness to pay or receive compensation[8], which is one of the common methods to determine the ecological compensation standard of small watersheds at this stage. However, the conditional value method is an investigation of the wishes of stakeholders, and there are many subjective factors, which may lead to deviations in the final results, so it can not accurately reflect the inner true wishes of the compensators and the indemnitees. In addition, both the compensators and the recipients are based on the study of the compensation subject, and the overall value standard of ecological compensation in small watershed areas has not been clearly defined. In its 2006 policy report, the China Council for international cooperation on environment and development said, “if the market value of ecosystem services can be accurately assessed and quantified, it should be the best basis for measuring the standard of ecological compensation”.

To sum up, in the existing research on the ecological compensation standard of the small watershed by using the ecological service function value method, there are still the following deficiencies: first, most of the compensation amount is measured by the ecological service function value, and all the ecological service functions of the ecosystem in the watershed are included in the scope of ecological compensation, and the boundary and scope of compensable ecological service functions are not clear; second, the calculation of ecosystem service function value is not aimed at the ecological function within the compensable range that the system can provide. The boundary between theory and practice is relatively vague, and there is also a lack

of clear definition. Based on the existing literature results, this paper attempts to make contributions to the study of small watershed ecological compensation standards. Therefore, based on the value of ecosystem service functions, utility factor and equivalent factor models are introduced to distinguish the compensated and non-compensated ecosystem service functions, and the equivalent factors that different ecosystems can provide compensated ecological functions are expressed so that the determination of ecological compensation amount is scientific More accurate, and then provide a basis for the determination of ecological compensation standards in small watersheds.

2. Overview of the study area and data sources

Changtian small watershed is located in Xixiu District, Anshun City, 105°08'–106º26'E and 25º04'–25º20'N. The climate belongs to the north subtropical humid monsoon climate, which is characterized by rainy and hot seasons, warm and wet seasons, with an average annual temperature of 14 ℃ and an average rainfall of 1,300 mm for many years. The landform of the basin is mainly a peak cluster depression landform, with an average altitude of about 1,310.65 m and a total area of 13.43 km², the area of water and soil loss is 7.17 km^2. The agricultural industrial structure in the basin is dominated by agricultural production, and the economic income of local residents is dominated by planting rice and flue-cured tobacco. According to statistical data, the total GDP of the small watershed of Laotian in 2018 was 29.8615 million yuan, and the total agricultural output value was 6.2392 million yuan, of which the output value of the planting industry was 3.5432 million yuan, the output value of animal husbandry was 881,000 yuan, and the output value of sideline industry was 1.815 million yuan. The disposable income of rural residents was 2,132 yuan, and the total grain output was 1.468 million kg.

The total land area of this watershed is 13.43 km^2. Before the water and soil control project, the cultivated land area is 4.78 km^2, accounting for 35.60% of the total watershed area, the forest land area is 5.92 km^2, accounting for 44.00% of the watershed area, and the unused land (barren mountains and slopes) in other lands is 2.37 km^2, accounting for 17.00% of the watershed area. Due to a large number of sparse and young woodlands, barren mountains and slopes account for a certain proportion, and most of the existing cultivated land depends on the mountains, as well as some unreasonable agricultural cultivation and production and construction activities, the water and soil loss in Changtian small watershed began to become a more and more serious, mainly moderate and intensive loss, accounting for 54.81% of the loss area. Through the detailed investigation and statistics of water and soil loss in the watershed, the water and soil loss area of this small watershed is 7.17 km^2, it accounts for 53.00% of the total drainage area, of which the slight loss area is 3.28 km^2, accounting for 46.00% of the loss area. The moderate loss area is 2 km^2, accounting for 28.00% of the loss area. The intensity loss area is 1.88 km^2, accounting for 26.00% of the loss area. The average annual soil erosion modulus is 3600 t (/km^2 a), and the annual erosion is as high as 25,800 tons. Since December 2010, the Changtian small watershed in Xixiu District, Anshun City has begun to carry out soil erosion control with the goal of improving agricultural production conditions and ecological environment, improving people's living standards, and promoting the adjustment of rural industrial structure and the sustainable development of regional economy and society in the Changtian small watershed. Among them, the designed treatment area is 6.90 km^2, and the treatment degree is more than 86.00%. At present, the ecosystem of Changtian small watershed can be divided into five ecosystems: farmland, forest, water area, fruit forest land, and unused land, of which the farmland area is 4.78 km^2, the forest area is 5.92 km^2, the fruit forest area is 2.37 km^2, the water area is 0.09 km^2 and the unused land area is 0.28 km^2. The data sources of this paper include the data of the study area, from the statistical data released by the Guizhou Provincial Forestry Department and the Provincial Bureau of statistics, as well as the report data of the soil erosion control project of the Anshun Forestry Bureau and the Changtian small watershed in Xixiu District, and the local data provided by the village committees of local villages;

the social public data comes from the social public data and the relevant data of the National Statistical Yearbook published in the code for the evaluation of forest ecosystem functions (LY/T1721-2008).

3. Research methods

3.1 Calculation method of the ecological value of Changtian small watershed

3.1.1 Calculation method of the ecological value of forest land system

The fruit forest planted in Changtian small watershed to improve the ecosystem has a good market prospect. Planting Rosa roxburghii for several years at a time can harvest. Because trees and forests have similar ecological functions, the same method is used to calculate the ecosystem value of fruit forest and forest ecosystem. The forest area in Changtian small watershed is 5.92 km^2, and the planting area of fruit forest is 2.37 km^2. According to the LY/T1721-2008 evaluation specification established by the Chinese Academy of Forestry Based on its long-term observation data, the evaluation index system of forest ecosystem service function in Changtian small watershed is determined after improvement, and the formula is as follows:

$$P_k=\frac{P_f}{a_k}\times A_k \tag{1}$$

$$P_f=\sum A_k \times P_k \tag{2}$$

In formulas (1) and (2): k represents the specific type of evaluation index, P_f is the total ecological value of forest land ecosystem in Changtian small watershed (10,000 yuan /km^2), A_k is the unit area of the kth evaluation index in Changtian small watershed (km^2), P_k is the unit ecological value of the kth evaluation index, and P_f is the total ecological value of forest land ecosystem in Guizhou Province (10,000 yuan /km^2), A_k is the unit area (km^2) of the kth evaluation index in Guizhou Province.

3.1.2 Calculation method of the ecological value of farmland system

The farmland ecosystem in Changtian small watershed is mainly planted with rice and flue-cured tobacco, and the land type belongs to cultivated land. After consulting the sowing area, single grain yield, and the national average price of grain crops in Anshun, this paper uses the research of Xie *et al.*[9] on the value of equivalent factors and the calculation model method of farmland (cultivated land) ecological service value proposed by Liu *et al.*[10] for reference. The formula is as follows:

$$P_a=E_a\times A \tag{3}$$

Where: P_a represents the total ecological value of the farmland system in Changtian small watershed (10,000 yuan), E_a represents the value of unit equivalent factor (yuan /km^2), and A represents the total area of farmland in the region.

$$E_a=\sum\frac{m_i\times p_i\times q_i}{M} \tag{4}$$

Where: m_i refers to the planting area of the i-th food crop (km), p_i refers to the domestic average price of the i-th food crop (yuan /kg), q_i refers to the output of the i-th food crop (kg/km^2), and M refers to the total area of farmland.

3.1.3 Calculation method of the ecological value of water area system

The ecological value of the water area system in Changtian small watershed is measured by taking the water ecological service function as the index. The water ecological service function refers to a series of utilities that the water area ecosystem can bring to maintain the ecological environment while providing the natural environment for our human survival. The water ecological service functions of Changtian small watershed mainly include water resource accumulation, river sediment transport, soil conservation, carbon fixation, and biodiversity protection. This paper, combined with the water ecological value evaluation method proposed by Ouyang Zhiyun *et al.*[11] and the actual situation of the water system in Changtian small watershed, the formula for calculating the ecological value of the water system is as follows:

$$P_w = \sum P_n \times W_n \quad (5)$$

Where: n refers to different types of ecological service functions provided by the water system; P_n is the unit market price of the nth ecological service function; W_n is the material quality provided by Changtian small watershed in the nth function; P_2 refers to the total ecological value provided by the water system of Changtian small watershed.

3.2 Equivalent factor model of ecological compensation standard in Changtian small watershed

The value of ecological services provided by the ecosystem in the small watershed is provided through its ecological functions, and the value of ecological services provided is also the upper limit of ecological compensation. The classification of its ecological functions is specifically reflected in the services provided for ecology. According to the actual situation of the Changtian small watershed, the functions can be divided into four primary functions: supply function, regulation function, support function, and cultural function, Further subdivision can divide the four primary functions into 10 secondary functions, such as providing food, providing raw materials, supplying water resources, regulating gas, regulating climate, conserving water sources, purifying the environment, maintaining soil, protecting biodiversity, and providing landscape appreciation.

3.2.1 Determine the compensation scope of the small watershed ecological service function

As an equivalent factor, the service function provided by the ecosystem is an important factor to determine the standard of ecological compensation. However, from the perspective of compensation, ecological compensation is an economic means to adjust the relationship between interests and damage between regions in the basin. The specific implementation process needs to convert the value of ecological services provided by the ecosystem into the market monetary value. Therefore, in these equivalent factors, it is necessary to consider the spillover scope of each function and whether it can really improve the ecosystem. Among them, because the overflow range is too large, and the ecological function radiates to the whole country and even the world, it is impossible to determine the specific subject of ecological compensation, so the function of gas regulation and biodiversity protection cannot carry out the final ecological compensation. On the other hand, since the functions of providing food and raw materials are the natural characteristics of the ecosystem, they cannot increase the marginal benefits of the ecological value of small watersheds, so they cannot be included in the ecological compensation standard. See **Table 1** for the specific scope of compensation.

3.2.2 Determination of ecological compensation standard model

The five systems in Changtian small watershed have different ecological service functions, so the proportion of ecological compensation is also different, resulting in different final ecological compensation standards. The formula of ecological compensation standard is established by using the ecological value provided by the five systems:

$$P = \sum P_j \times e_{jg} \quad (6)$$

Where: P represents the total ecological compensation standard (10,000 yuan), P_j represents the total ecological value of the j^{th} ecosystem (10,000 yuan), and e_{jg} represents the equivalent factor value of the j^{th} ecosystem in the GTH compensable function.

3.2.3 Correction of equivalence factor table

When using the ecological value provided by the ecosystem to determine the ecological compensation standard in small watersheds, it is necessary to build an equivalent factor table. However, the equivalent factor table of ecosystem service value in China was established by Xie *et al.*[17] cannot be targeted at all small watersheds. Therefore, when determining the equivalent factor table in Changtian small watershed, it needs to be modified. This paper is based on the economic and natural environment of Changtian small watershed, combined with the actual ecological service functions and ecological resources brought about by the basin and its surrounding areas, the relevant ecological data pro-

vided by Anshun ecological environment bureau are selected, and corrected in combination with the table of equivalent factors of China's ecological service value. The correction principle is: for the ecological service functions of a specific ecosystem, the average value is selected if the difference is small in the measurement standard, and for those with a large difference, the average value is selected through the ecosystem. The correction formula is Formula (6). After correction, the compensated equivalent factors of the Changtian small watershed are shown in **Table 2**.

$$\bar{e}_{jg} = \frac{1}{l}\frac{S_k}{F_k} P_{jg}\, e_{0jg} \tag{7}$$

$$e_{jg} = \begin{cases} e_{0jg} & \left|\bar{e}_{jg} - e_{0jg}\right| \leqslant 0.5 \\ \bar{e}_{jg} & \left|\bar{e}_{jg} - e_{0jg}\right| > 0.5 \end{cases} \tag{8}$$

In formula (7) and formula (8): e_{jg} is the equivalent factor value of the jth ecosystem in the gth compensable function of Changtian small watershed; e_{0jg} is the equivalent factor value of the j^{th} ecosystem in the g^{th} compensable function in China; S_k is the value of ecosystem; F_k is the total area of the ecosystem; P_{jg} is the proportion of the g^{th} compensable function of the j^{th} ecosystem in the Changtian small watershed in the value of ecosystem services in China.

Table 1. Compensation scope of ecological service function in Changtian small watershed

Primary function	Secondary function	Beneficiary			Whether to improve the ecology		Whether it is included in the scope of compensation
		Within the basin	Whole country	Global	Yes	No	
Supply function	Provide food	√				√	
	Provide raw materials	√				√	
	Water supply	√			√		√
Adjustment function	Regulating gas			√	√		
	Regulate the climate	√			√		√
	Water conservation	√			√		√
	Environmental purification	√			√		√
Support functions	Maintain soil	√			√		√
	Protect biodiversity			√	√		
Cultural function	Provide appreciative landscape		√		√		√

Table 2. Compensated equivalent factors of Changtian small watershed (Unit: × 10^{-3})

Compensable function	Farmland	Forest	Waters	Fruit forest	Unused land
Water supply	-1.68	0.40	23.09	0.35	-0.72
Regulate the climate	0.83	2.52	5.33	2.40	0.05
Water conservation	2.69	6.74	18.08	5.21	0.03
Clean the situation	1.64	2.14	10.09	1.26	0.01
Maintain soil	1.34	3.91	0.65	3.68	0.08
Provide appreciative landscape	0.02	0.86	2.11	0.92	0.32
Total	4.84	16.57	59.35	13.82	-0.23

4. Results and analysis

4.1 Comprehensive evaluation of ecological service function value of Changtian small watershed

4.1.1 Ecological service function value of forest land system

According to **Table 3**, the total ecological value of the forest ecosystem in Changtian small watershed is 454.656 million yuan. Among them, the forest ecosystem has the highest ecological value in water conservation and air purification, which are 130.24 million yuan and 126.688 million yuan respectively. It can be seen that water conservation and air purification are the two service functions that provide the highest service value for the ecosystem, and the ecological value per square kilometer is 22 million yuan and 21.4 million yuan respectively; biodiversity protection and carbon sequestration and oxygen release take the second place, with the ecological value of 14.7 million yuan and 12 million yuan per square kilometer respectively; then there is the function of soil conservation and nutrient accumulation. The biological value per

square kilometer is 4.7 million yuan and 1.4 million yuan respectively; the unit value provided by forest recreation is the least, only 600,000 yuan per square kilometer, and the ecological value provided by the forest ecosystem in Changtian small watershed in the forest recreation function is 3.552 million yuan.

Table 3. Evaluation index and ecological value of forest ecosystem in Changtian small watershed

Evaluating indicator	A_k/km^2	P_k/10,000 Yuan	Ecological value/10,000 Yuan
Water conservation	5.92	2,200	13,024
Purify the atmosphere	5.92	2,140	12,668.80
Biodiversity conservation	5.92	1,470	8,702.40
Carbon fixation and oxygen release	5.92	1,200	7,104
Soil conservation	5.92	470	2,782.40
Accumulate nutrients	5.92	140	828.80
Forest Recreation	5.92	60	355.20
Total	—	—	45,465.60

The ecological service function value provided by the fruit forest ecosystem in Changtian small watershed is 182.016 million yuan (**Table 4**). Like the forest ecosystem, it provides the most value in water conservation and air purification, with 52.14 million yuan and 50.718 million yuan respectively; biodiversity conservation and carbon sequestration and oxygen release followed, with 34.839 million yuan and 28.44 million yuan respectively; the value of forest recreation function is the least, only 1.422 million yuan. The forest and fruit forest ecosystem account for the largest proportion of the process of ecological compensation. The government can compensate in the future compensation process by putting fruit seedlings, building forest farms, and other capital investment methods. At the same time, it can also use technical support to carry out technical training for fruit farmers, so as to promote economic prosperity in the basin while the environment is beautiful.

4.1.2 Ecosystem service function value of water area system

The ecological value provided by Changtian small watershed in terms of water ecosystem is 4.314 million yuan (**Table 5**). The ecological service functions provided by the water ecosystem mainly include water resource accumulation, river sediment transport, soil conservation, carbon fixation, biodiversity protection, etc. Among them, the value provided in soil conservation is the largest, which is 3.6606 million yuan; carbon fixation takes second place, with 564,000 yuan. Although the value provided is the second, compared with the soil conservation function ranking first, the gap is large, with a difference of 3,096,600 yuan; the value provided by water resources accumulation, river sediment transport function, and biodiversity protection is relatively small, which are 44,200 yuan, 13,600 yuan, and 31,600 yuan, respectively.

Table 4. Evaluation index and ecological value of fruit and tree forest ecosystem in Changtian small watershed

Evaluating indicator	A_k/km^2	P_k/10,000 Yuan	Ecological value/10,000 Yuan
Water conservation	2.37	2,200	5,214
Purify the atmosphere	2.37	2,140	5,071.80
Biodiversity conservation	2.37	1,470	3,483.90
Carbon fixation and oxygen release	2.37	1,200	2,844
Soil conservation	2.37	470	1,113.90
Accumulate nutrients	2.37	140	331.80
Forest Recreation	2.37	60	142.20
Total	—	—	18,201.60

Table 5. Ecosystem service function and ecological value of waters in Changtian small watershed

Function type	W_n	P_n	Ecological value/10,000 Yuan
Water resources accumulation	6.60/10^4 m^3	0.67/(yuan/m^3)	4.42
River sediment transport function	4.40/10^6 kg	3.10/(yuan/kg)	1.36
Maintain soil	405.79/km^2	9,020.87/(yuan/km^2)	366.06
Carbon fixation	3.34/10^7 kg	168.85/(yuan/kgc)	56.40
Protect biodiversity	8.72/km^2	3,633.60/(yuan/km^2)	3.16
Total	—	—	431.40

Changtian small watershed has a small ecological area, but it accounts for a significant propor-

tion of the four primary functions of supply function, regulation function, support function, and cultural function. The ecological significance of the water system is quite significant. Therefore, in terms of water compensation, we can make reasonable planning through the form of capital investment, such as building reservoirs, and building and beautifying rivers and lakes, so as to maximize the ecological value of the water ecosystem.

4.1.3 Total value of ecological service function in Changtian small watershed

The ecological value provided by the ecosystem of Changtian small watershed totals 913.586 million yuan. Among them, the forest system provides the most ecological value, reaching 454.656 million yuan. This is because the forest system has more ecological functions, so it can provide higher external value; the calculation model of the ecological value of fruit forest is consistent with that of the forest, but because the planting area of fruit forest is less than that of the forest, 5 conclusions and policy enlightenment unit: 10,000 yuan, so the ecological value of fruit forest is lower than that of the forest system. Due to the small area of the water system in Changtian small watershed, the ecological value provided is also small, only 4,314,000 yuan. However, the equivalent factor of the water system in providing ecological services, especially in the compensable function, is very high, as high as 59.35. It can be seen that the water system is the optimal system to purify the environment and maintain a good ecosystem. In addition, most of the unused land is the residence of farmers and the land for construction and development, which cannot provide services for improving the ecological environment and does not have the value of ecological externality.

4.2 Comprehensive evaluation of ecological compensation standards in Changtian small watershed

Through the calculation of the ecological value of five ecosystems, the equivalent factor model is established, and the ecological compensation amount of Changtian small watershed is 11.624 5 million yuan. Among them, the compensation amount for the farmland system is 1,319,400 yuan, the compensation amount for the forest system is 7,533,600 yuan, the compensation amount for the water area system is 256,000 yuan (accounting for 2.20% of the total compensation), and the compensation amount of fruit forest system is 2,515,500 yuan. Because the ecological value of unused land is 0 yuan, no compensation measures are taken for the unused land system. The current ecological value of the Changtian small watershed in the Xixiu District of Anshun City is the result of the local government's soil erosion control. The total investment in the implementation of the project is 2.53 million yuan, of which the cost of engineering measures is 1.011 million yuan, the cost of plant measures is 1.2562 million yuan, and the cost of ecological restoration measures is 60,200 yuan, and the independent cost is 202,500 yuan. As the water and soil loss control project has improved the ecology and belongs to the scope of compensation, the project funds invested by the government should be removed in the compensation process, and the final ecological compensation standard of Changtian small watershed is 9.0945 million yuan.

From **Table 6** and the above description, it can be seen that the area of farmland ecosystem in Changtian small watershed accounts for 35.60%, and the compensation accounts for 11.35%; the proportion of forest ecosystem area is 44.00%, and the proportion of compensation is 64.80%; the area of fruit forest ecosystem accounts for 17.70%, and the compensation accounts for 21.64%; the area of water ecosystem accounts for 0.05%, and the compensation accounts for 2.20%; the proportion of the unused land area is 2.10%, and the compensation proportion is 0. From the balanced proportion of area and compensation, it can be seen that the water area system is not only the best system to provide ecological services but also the highest proportion of compensation, followed by the forest and fruit tree forest ecosystem. Therefore, the Changtian small watershed can develop more in the water area and fruit tree forest system in the future, especially in terms of aquaculture and planting fruit trees in the water area, which not only provides ecological services but also is conducive to the expansion of economic scale. The total ecological compensation of Changtian small watershed accounts for 38.93%

of the local GDP, and the compensation method supported by funds is a good choice. Of course, the ways of ecological compensation are diversified, and the diversified combination of financial compensation, technical compensation, and policy compensation has more practical and long-term significance than simple financial compensation.

Table 6. Results of ecological compensation in Changtian small watershed (Unit: ten thousand yuan)

Farmland	Forest	Waters	Fruit forest	Unused land	Total
131.94	753.36	25.60	251.55	0	1,162.45

5. Conclusions and policy implications

Taking the ecological value provided by the ecosystem service function as the standard of ecological compensation has a theoretical basis and practical operability. The positive external utility of the ecosystem itself cannot be measured by real money, but the development opportunities sacrificed for protecting and improving the ecosystem need to be balanced through external compensation. Based on the previous research on the ecological compensation standard of the small watershed, considering the value of ecological service function brought by the ecosystem to the environment, and its ecological value, the corresponding ecological service functions of different ecosystems have different utility factors, this paper proposes an equivalent factor model and determines the amount of ecological compensation of Changtian small watershed in combination with the actual resource utilization and development of Xixiu District, Anshun City. The result is 11.6245 million yuan, excluding the project funds, the compensation standard amount is 9.0945 million yuan. This data is the upper limit of ecological compensation. The lower limit of ecological compensation also needs to take into account the subjective will of the compensation object and the willingness to pay off the compensation subject. When calculating the lower limit of ecological compensation, the commonly used methods are the opportunity cost method, willingness survey method, etc. Because each method has its limitations, it is recommended to combine them for better calculation. This problem is also the main research direction for small watershed ecological compensation in the future.

When implementing compensation measures, the local government can consider both macro and micro levels. At the macro level, corresponding policies and funds can be introduced to the whole small watershed for ecological engineering construction and technical training. From the micro level, taking into account the local actual situation, the ecological fruit forest resources such as *Rosa roxburghii* fruit trees can be invested in batches to protect the ecology and promote the local economic development at the same time. In addition, considering the small area of the water system in the Changtian small watershed, reservoirs can be built here to ensure the normal daily water use of residents. When determining the ecological compensation standard, this paper fully considers the actual development of Changtian small watershed and the current relevant market prices in China, which has reference value and significance for the local government in the implementation of compensation measures.

Conflict of interest

The authors declare that they have no conflict of interest.

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