

Article

An Assessment of the Rational Range of Eco-Compensation Standards: A Case Study in the Nujiang Prefecture, Southwestern China

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Abstract: Eco-compensation is an effective means of coordinating ecological protection and economic development, and the assessment of its standards is core content in the study of eco-compensation projects. To improve the operability of eco-compensation standards, taking Nujiang Prefecture as the study area, we combine the equivalent factor method and water footprint method to evaluate the ecosystem-service-value (ESV) spillover and use the market comparison method to calculate the opportunity cost. The final eco-compensation upper and lower limits model is constructed on the basis of the ESV spillover and opportunity cost. The results show the following: (1) the ecological protection of Nujiang Prefecture has been effective, based on the stabilization of its ESV after an initial increase. The main types of ecosystem services provided are regulation and provision services. Gongshan County makes the most significant contribution to the total ESV. (2) The ratio of the ESV self-consumption in Nujiang Prefecture shows a trend of first rising and then falling. This is mainly explained through the reduction in the use of industrial and agricultural water. After deducting self-consumption through the water footprint method, it can be observed that there is ecological spillover in Nujiang Prefecture. (3) The opportunity cost in Nujiang Prefecture increases yearly from 2005 to 2020 owing to ecological protection policies. Combined with the ESV spillover, it is determined that the rational range of the eco-compensation standard is between CNY 6.17×10^2 million and 120.01×10^2 million in 2005, between CNY 10.02×10^2 million and 128.25×10^2 million in 2010, between CNY 30.34×10^2 million and 197.12×10^2 million in 2015, and between CNY 41.97×10^2 million and 227.52×10^2 million in 2020. The current study can offer decision makers a more flexible eco-compensation standard while coordinating the contradiction between regional ecological protection and economic development.

Keywords: eco-compensation; ecosystem service value; opportunity cost



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1. Introduction

Dietze et al. defined ecosystem services as “nature’s contribution to people”. That is, ecosystems provide a large number of products and services for human beings [1]. However, dramatic changes in land-use patterns, such as rapid urbanization and transformation for agriculture and forestry, have had a considerable impact on the ecosystems [2,3]. It has brought about a series of challenges, including environmental pollution, climate change, loss of species, and the degradation of ecosystem functions [4–7], which ultimately undermines the wellbeing of humans themselves. Much effort has been expended in responding to these environmental crises. Among them, payment for ecosystem services (PESs) can maintain the sustainable use of ecosystems through economic means and regulate the relationship between stakeholders. As a result, it has been the subject of numerous theoretical studies and practices worldwide [8–11].

Eco-compensation is a term commonly used in China to describe PESs [12]. Relevant practices in developed countries mostly use watersheds or specific regions as the market scope and trade various ecosystem services as commodities. In contrast to the market behavior widely used in developed countries, China's market-oriented eco-compensation is only conducted in a few regions due to economic and development constraints, and eco-compensation projects are mostly government led. China has established a variety of eco-compensation projects for promoting sustainable socioeconomic development [13], for example, watershed [14], forest [15], farmland [16,17], grassland [18] eco-compensation forms. In 2010, China issued the National Plan for Main Functional Zones (NPMFZ), which specifies that the National Key Ecological Functional Zone is targeted at safeguarding national ecological security and restricts large-scale, high-intensity industrial development in this zone [19,20]. It serves as a spatial control tool for regional development. Meanwhile, as a strategic, basic, and binding form of planning, it can provide guidance for the delineation of ecological protection red line and the allocation of construction land indexes, being organically integrated into the territorial spatial planning system, so as to have a certain indirect role in guiding land-use decisions. In order to encourage ecological protection, China introduced the fiscal transfer payment method matching with the NPMFZ in 2011, which serves to provide eco-compensation for the National Key Ecological Functional Zone [21].

Eco-compensation standards are at the core of eco-compensation project research because they are correlated with the success of eco-compensation policy implementation [22]. Researchers have recently investigated a number of quantitative assessment methods related to setting compensation requirements, including the contingent valuation method (CVM) [23–26], the ecosystem-service-value method [27,28], and the opportunity cost method [29]. The conclusions of these methods often vary considerably in practical applications [30]. The CVM investigates the willingness to pay and be paid by the interested parties under market conditions based on the principle of utility maximization. This method is convenient for obtaining survey information, but it is heavily influenced by subjective considerations [31] that make it challenging to address the imbalance between a willingness to pay (WTP) and willingness to accept (WTA) [23]. The ecosystem-service-value approach can allow for the accurate evaluation of the ESV from the perspective of ecosystem service suppliers [27]. In contrast, its assessed values are frequently excessive [32], which could be used as a theoretical upper limit for eco-compensation standards [33]. Opportunity costs are more regularly employed, but some of them can be challenging to measure, and whether their inputs and ecological outputs are equivalent is easily overlooked [21]. In general, the opportunity cost method can be used to determine the lower limit of the eco-compensation standard [32]. Many studies have shown that ecological compensation standards at present are unreasonable [34,35]. First of all, there is a general problem that the eco-compensation standard is too low. This will dampen the enthusiasm for ecological protection and is not conducive to the sustainability of the eco-compensation policy; secondly, most of the previous studies were based on a single ecological compensation standard. A single standard is one-sided, and it is difficult to adjust flexibly according to actual needs. For example, the assessment of ecosystem service value often far exceeds the government's financial capacity, resulting in a reduction in the operability of eco-compensation standards. Therefore, it is necessary to seek a rational range of eco-compensation standards.

Nujiang Prefecture is not only one of the deep-poverty areas in China, but also a biodiversity hotspot [36] and the core zone of the Three Parallel Rivers, a world natural heritage site, which has a very important ecological status in the country. A handful of ecological protection policies have been put into place in this area. Based on the above, the present study uses Nujiang Prefecture as an example, and firstly selects the equivalent factor method to analyze the variations in ESV before and after the implementation of eco-compensation from 2005 to 2020. Subsequently, a market comparison method is used to assess the opportunity cost of the loss of ecological conservation in Nujiang Pre-

fecture. Finally, an upper- and lower-limit model is built to assess a rational range of eco-compensation standards in Nujiang Prefecture based on the ESV and opportunity cost.

2. Materials and Methods

2.1. Theoretical Framework

“Externality” theory is an essential theoretical basis for eco-compensation. It refers to an external benefit or cost to some resulting from the activities of others [37]. The utilization of natural resources often has externalities. It is precisely because of this externality that the phenomenon of “free-riding” prevails, and the interests of all parties are difficult to coordinate. Eco-compensation can internalize the external cost of the ecological environment by economic means [38]. The current study builds a theoretical framework based on the externality theory, as shown in Figure 1.

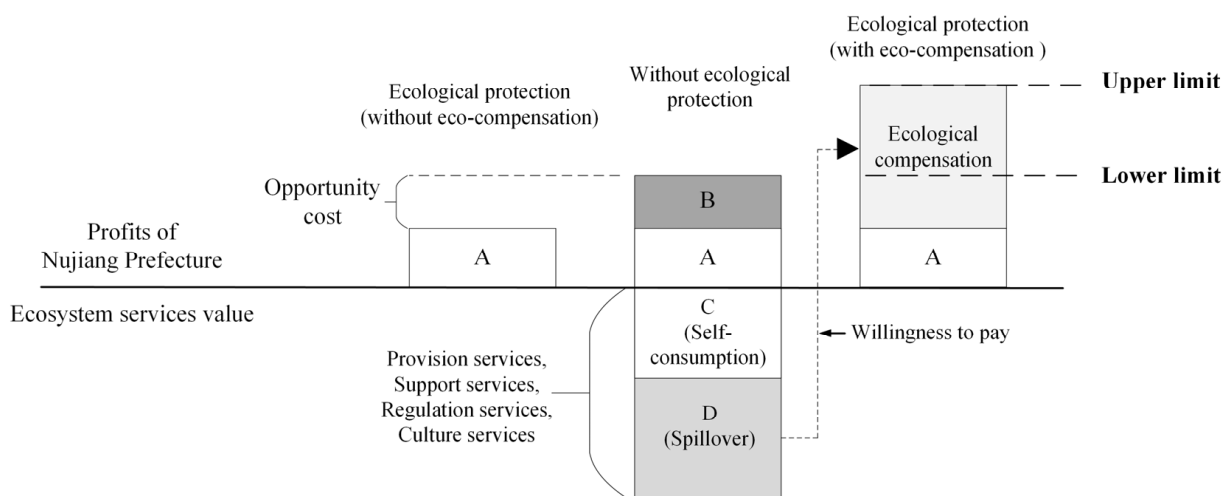


Figure 1. Theoretical analysis framework.

In the case of ecological protection (without eco-compensation), it is presumed that the ecosystem service provider is able to obtain benefit A. As a result of ecological protection, ecosystem service providers offer significant ecological goods (ecosystem services) at the expense of their development opportunities [22]. As rational economic agents, ecosystem service providers alter the status quo of land use for financial gain when the eco-compensation standard is lower than its expended opportunity cost B, causing negative environmental externalities [39], such as deteriorating water quality and the loss of carbon sinks. This increases the cost of living for people in downstream areas and reduces the overall ESVs of the basin by C + D. Therefore, eco-compensation fails to stimulate ecological protection behavior; downstream beneficiaries are also reluctant to pay where the standard is higher than the ESV spillover D provided by ecosystem service providers. Logically, the only situation where ecosystem service providers and consumers can rationally come to an agreement is when the compensation standard falls somewhere in between. Since most ecosystem services are non-market products, people’s willingness to pay needs to be taken into account when calculating the compensation standards. The opportunity cost B is the lower limit of the eco-compensation standard, and the ESV considering the willingness to pay is the upper-limit reference of the eco-compensation standard.

2.2. Study Area

Nujiang Prefecture, which has jurisdiction over Lushui City, Fugong County, Gongshan County, and Lanping County, is situated on the northwest border of Yunnan Province, China (98°39′ E–99°39′ E, 25°33′ N–28°33′ N). It has a total area of about 1.45×10^4 km² and its elevation is 739–5075 m (Figure 2). As a whole, Nujiang Prefecture belongs to the National Key Ecological Function Area. Included are the Gaoligong Mountain National

Nature Reserve and Yunling Provincial Nature Reserve. The prefecture has a unique topography, diverse ecosystem types, rich biological resources, and a forest coverage rate of 78.90%. Nevertheless, Nujiang Prefecture is also one of the country's most deeply impoverished regions. Taking the year 2018 as an example, its per capita GDP was CNY 30,800, only 21.12% of Shanghai's per capita GDP. There is a general contradiction between ecological protection and poverty alleviation. With the promotion of poverty-alleviation and poverty-reduction policies, Nujiang Prefecture has undergone tremendous socioeconomic changes. Nujiang Prefecture is facing the dilemma that its economic development is being constrained by environmental protection.

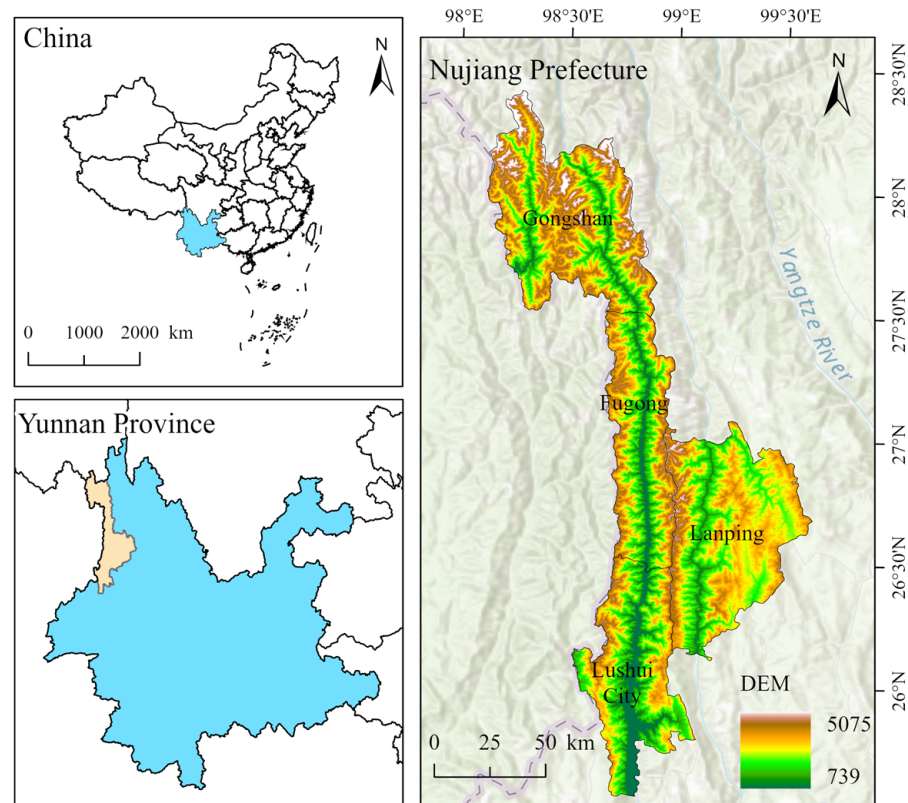


Figure 2. Location of the study area and its elevation spatial distribution pattern.

2.3. Methods

2.3.1. Ecosystem-Service-Value Method

Costanza et al. [40] presented a precise definition and classification of the ecosystem services offered by an ecosystem and its components. They estimated the global ecosystem service value by dividing them into two categories based on whether or not they are marketable. Xie et al. [41,42] modified the ecosystem-service-value coefficients proposed by Costanza et al. and put forth a system of ecosystem-service-value equivalent factors applicable to China. In the current study, we used the revised model of ecosystem service value by Xie et al. [41] to evaluate the ecosystem service value of Nujiang Prefecture.

(1) Standard unit ecosystem-service-value equivalent factor

The potential contribution of different ecosystem types to ecological service function can be quantified by the standard unit ecosystem-service-value equivalent factor. Xie et al. [41] defined the standard unit ecosystem-service-value equivalent factor as the economic value of annual natural grain output of 1 hm² farmland, which is equal to 1/7 of the economic value of annual current grain output of 1 hm² farmland. It can be calculated as follows:

$$C = \frac{1}{7}P \times Q \quad (1)$$

where C (CNY/hm²) is a standard unit ecosystem-service-value equivalent factor; P (CNY/kg) is the average grain price; and Q (kg/hm²) is the average grain yield in the study area.

(2) Estimating the ecosystem service value

The calculation formula of ecosystem service value in the study area is:

$$VC_j = Ef_{vj} \times C \quad (2)$$

$$ESV = \sum_{j=1}^n (A_j \times VC_j) \quad (3)$$

where VC_j (CNY/hm²) is the ecosystem-service-value coefficient of land-use type j ; Ef_{vj} is the modified ecosystem-service-value equivalent of land-use type j ; C is a standard unit ecosystem-service-value equivalent factor; and ESV (CNY) is the ecosystem service value; A_j (hm²) is the area of land-use type j . Table 1 was created by referring to Nujiang Prefecture's land-use and land-cover data and the Xie *s'* table of ecosystem service equivalents per unit area. According to the relevant research [43], the ecosystem service of construction land was not considered, and it was assigned a value of 0.

Table 1. Ecosystem services equivalent factors in Nujiang Prefecture.

Classification of Ecosystem Services		Farmland	Forestland	Grassland	Waterbody	Unused Land
Primary Type	Secondary Type					
Provision services	Food production	1.11	0.25	0.23	0.80	0.01
	Raw material	0.25	0.58	0.34	0.23	0.01
	Water provision	−1.31	0.30	0.19	8.29	0.01
Regulation services	Air regulation	0.89	1.91	1.21	0.77	0.07
	Climate regulation	0.46	5.71	3.19	2.29	0.05
	Environment purification	0.13	1.67	1.05	5.55	0.20
Support services	Hydrological regulation	1.50	3.74	2.34	102.24	0.12
	Soil conservation	0.52	2.32	1.47	0.93	0.07
	Nutrients-cycle maintenance	0.16	0.17	0.11	0.07	0.01
Culture services	Biodiversity	0.17	2.12	1.34	2.55	0.07
	Aesthetic landscape	0.07	0.93	0.59	1.89	0.03
Total		3.95	19.70	12.06	125.61	0.65

2.3.2. Water Footprint Method

Water footprint theory can be used to reasonably measure the number of water resources used in a specified period, reflecting the ecosystem service value of its consumption. Therefore, referring to previous studies [44,45], we constructed a self-consumption model of ESV on the basis of the water footprint theory. Nujiang Prefecture's utilization of ecosystem services is expressed by comparing the water footprint with the water resources available. The calculation formula is as follows:

$$V_s = EV \times \frac{D_{water}}{S_{water}} \quad (4)$$

where V_s represents the ecosystem service value consumed by Nujiang Prefecture; EV represents the ecosystem services value in Nujiang Prefecture; D_{water} represents the demand for water resources in Nujiang prefecture, which is calculated by the water footprint; and S_{water} represents the water available. Referring to the previous research [46], it was calculated as 30% of total water resources.

The water footprint calculation can be divided into water for agriculture, water for industry, water for human life, and water for ecology [45,46]. There is a lot of virtual water in agriculture, and less in other sectors. Therefore, in the present study, the agricultural water footprint was calculated separately, and the water consumption of other sectors was calculated according to the actual usage. The calculation of the agricultural water footprint can be divided into agricultural and animal products. Based on the Penman–Monteith formula [47] recommended by FAO, we calculated the water requirements for the growth of main agricultural products. First, calculate the reference crop evapotranspiration ET_0 (mm) under climatic factors:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (5)$$

where R_n indicates the net radiation on the crop surface ($\text{MJ}/\text{m}^2 \cdot \text{d}$); G indicates soil heat flux ($\text{MJ}/\text{m}^2 \cdot \text{d}$); γ indicates psychrometer constant ($\text{kPa}/^\circ\text{C}$); T indicates average temperature ($^\circ\text{C}$); U_2 indicates the wind speed at a height of 2 m above the ground (m/s); e_s indicates saturation vapor pressure (kPa); e_a indicates measured water vapor pressure (kPa); and Δ indicates slope of correlation curve between saturated vapor pressure and temperature ($\text{kPa}/^\circ\text{C}$).

Using the crop coefficient K_c , ET_0 is then adjusted to obtain the water demand of crops ET_c (mm).

$$ET_c = K_c \times ET_0 \quad (6)$$

$$AWF_i = \frac{10 \sum_{i=1}^n ET_c}{CY_i} \quad (7)$$

where $10 \sum_{i=1}^n ET_c$ is the water requirement per unit area of crops; CY_i is the crop yield per unit area; and AWF_i is the virtual water content of crops. The specific calculation is realized via the CROPWAT 8.0 model developed over the standard Penman–Monteith formula and the CLIMWAT 2.0 database.

Since most of the ecosystem services are non-market products, the public's awareness of the ecological environment and standard of living determine their willingness to pay for ecosystem services. Therefore, the compensation standard should take into account compensators' willingness to pay based on ESV. As a non-exclusive public good, people's willingness to pay for ecosystem services increases with the level of living and economic development [48], showing a curvilinear growth state resembling an S-shaped Pearl growth curve [49]. Hence, with the help of the S-shaped Pearl growth curve, we used the Engel coefficient to quantify the economic development and improvement of the people's living in the study area to obtain the ecological compensation correction factor regarding the willingness to pay. The calculation formula is:

$$r = \frac{1}{1 + e^{-t}} \quad (8)$$

The upper limit of Nujiang Prefecture eco-compensation standard is:

$$C = (EV - V_S) \times r \quad (9)$$

where C is the upper limit of final eco-compensation; r is the eco-compensation correction coefficient; e is the natural logarithm; and $t = E_n^{-1} - 3$, E_n is the regional Engel coefficient.

2.3.3. Opportunity Cost Method

Opportunity cost is defined in economics as “what you give up in making one decision but not another” [50]. When applied to the field of eco-compensation, it refers to the benefits that the subject gives up for the protection of the ecological environment. Various methods are used to estimate opportunity costs. Limited by the availability of county-level statistical indicators, the current study selected the market comparison method that was the most commonly used and had the most relaxed requirements for indicators. That is, comparing the reference area with the study area in terms of the per capita local fiscal revenue, per capita net income of rural residents, and per capita disposable income of urban residents [34], to indicate the opportunity cost of local government and residents. The calculation formula is:

$$C = (G_0 - G) \times P + (R_0 - R) \times P_R + (U_0 - U) \times P_U \quad (10)$$

where G_0 , G , R_0 , R , U_0 , U are the per capita local fiscal revenue (G), per capita disposable income of urban residents (R), and per capita net income of rural residents (U) in the reference area and the study area, respectively; P , P_R , P_U are the total population, urban population, and rural population in the study area, respectively.

2.4. Data Source

The study's primary data sources were as follows: (1) land-use and land-cover data in 2005, 2010, 2015, and 2020 were derived from the Resource and Environment Science and Data Center of the Chinese Academy of Sciences (<https://www.resdc.cn>, accessed on 6 June 2022). These data are based on artificial visual interpretation of Landsat TM/ETM remote sensing images, where the accuracy is more than 90% [22]. Based on the reality and research needs of the study area, it was divided into six types of land use: farmland (including dry land and paddy field), forest land (including shrub forest, sparse forest land, etc.), grassland (including high-, middle-, and low-coverage grassland), waterbody (including ponds, wetlands, etc.), construction land (including urban construction land, rural construction land, industrial and mining land, etc.), and unused land (including desert, bare land, etc.). The DEM data were obtained from the geospatial data cloud platform (<http://www.gscloud.cn>, accessed on 6 June 2022). (2) The main crop planting area, yield, and average price data were obtained from the statistical yearbook of Yunnan Province, the statistical yearbook of Nujiang Prefecture, the national economic bulletin, and the social development bulletin of Nujiang Prefecture in 2005, 2010, 2015, and 2020. Data on water consumption were obtained from the Nujiang Water Resources Bulletin. Some missing data were supplemented by the interpolation method. (3) The data required by the CROP-WAT model to evaluate crop water requirements were derived from FAO's CLIMWAT2.0 database, including soil, air temperature, precipitation, irrigation schedule, etc.

3. Results

3.1. Spatia—Temporal Evolution of ESVs in Nujiang Prefecture

According to the relevant data on economic development and agricultural production in Nujiang Prefecture, five main food crops, including rice, wheat, corn, soybean, and potato, were selected for calculation. Taking into account the accessibility and comparability of data, we calculated with the average grain yield per unit of grain in Nujiang Prefecture from 2016 to 2020 and the grain price in 2020. As estimated by Formula (1), the value of an ecosystem service equivalent factor in Nujiang Prefecture was 1427.87 CNY/hm². Combined with the equivalent factor weights of different ecosystems, we calculated the ESVs of Nujiang Prefecture from 2005 to 2020 as presented in Figure 3 and Table 2.

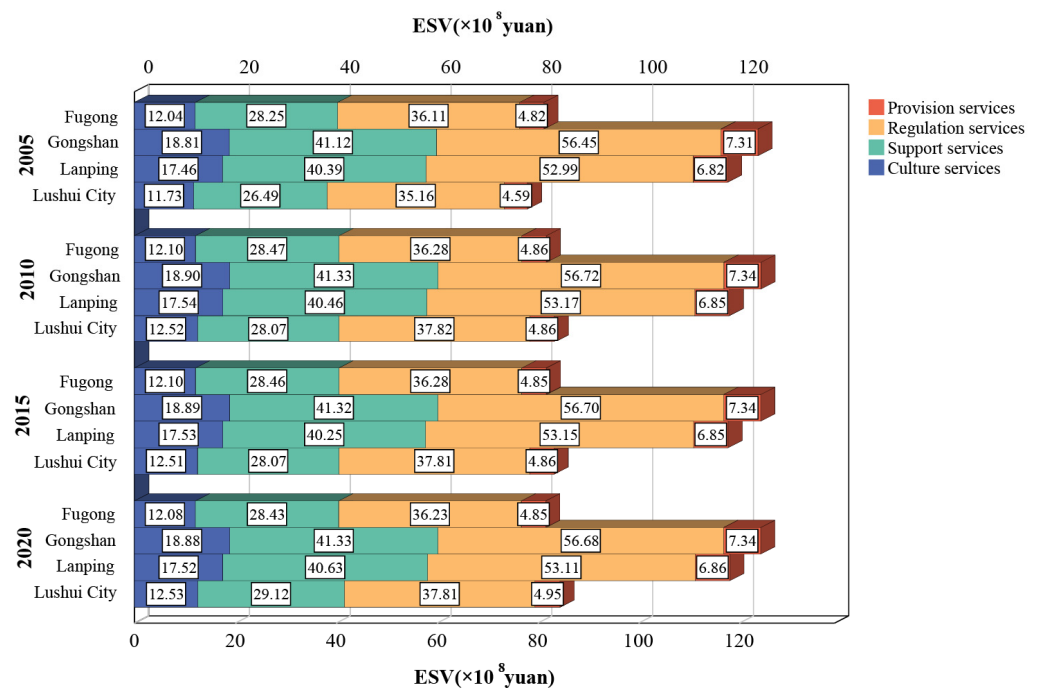


Figure 3. ESVs of counties in Nujiang Prefecture from 2005 to 2020.

Table 2. Temporal evolution characteristics of ESVs in Nujiang Prefecture (×CNY 10² million).

Primary Type	Secondary Type	2005	2010	2015	2020
Provision services	Food production	6.86	6.78	6.78	6.78
	Raw material	11.45	11.64	11.64	11.63
	Water provision	5.23	5.48	5.48	5.60
Regulation services	Air regulation	38.30	38.85	38.84	38.80
	Climate regulation	109.04	111.20	111.17	111.07
	Environment purification	33.37	33.93	33.92	33.96
Support services	Hydrological regulation	86.64	87.96	87.94	89.20
	Soil conservation	45.94	46.67	46.66	46.61
	Nutrients-cycle maintenance	3.66	3.70	3.70	3.70
Culture services	Biodiversity	41.66	42.36	42.34	42.33
	Aesthetic landscape	18.39	18.69	18.69	18.69
Total		400.54	407.29	407.17	408.36

As evidenced by Figure 3 and Table 2, the ecosystem service value of Nujiang Prefecture in 2005, 2010, 2015, and 2020 are CNY 400.54×10^2 million, CNY 407.29×10^2 million, CNY 407.17×10^2 million, and CNY 408.36×10^2 million, respectively. From the perspective of service content, regulation and provision services have always been the core primary-type functions of the ecosystem services of Nujiang Prefecture. The main secondary-type functions provided by Nujiang Prefecture are climate regulation, hydrological regulation, and soil conservation. From the perspective of the ESV value, the ESV of Nujiang Prefecture first increases and then remains stable. ESV increased between 2005 and 2010 while stabilizing between 2010 and 2020. The ESVs of Fugong County from 2005 to 2020 were CNY 81.22×10^2 million, CNY 81.71×10^2 million, CNY 81.69×10^2 million, and CNY 81.59×10^2 million; the ESVs in Gongshan County from 2005 to 2020 were CNY 123.69×10^2 million, CNY 124.29×10^2 million, CNY 124.25×10^2 million, and CNY 124.23×10^2 million; and the ESVs in Lanping County from 2005 to 2020 were CNY 117.66×10^2 million, CNY 118.02×10^2 million, CNY 117.78×10^2 million, and CNY 118.12×10^2 million, respectively. The ESVs in Lushui City from 2005 to 2020 were

CNY 77.97×10^2 million, CNY 83.27×10^2 million, CNY 83.25×10^2 million, and CNY 84.41×10^2 million, respectively. It can be observed that the ESVs in the four counties showed an increasing trend. Among the four counties in Nujiang Prefecture, Gongshan County contributed the most to the overall ecosystem service value. This was because the Gaoligong Mountain National Nature Reserve, which has strict ecological protection policies, retained relatively primitive vegetation and provided many ecosystem services. In terms of the ESV per unit area provided by the four counties, Fugong County increased from 26,214.54 to 26,333.97 CNY/hm², Gongshan County increased from 24,860.76 to 24,969.30 CNY/hm², Lanping County increased from 23,980.64 to 24,074.40 CNY/hm², and Lushui City increased from 22,519.12 to 24,379.10 CNY/hm². Fugong County had the largest ecosystem service value per unit area, while Lushui City had the largest increase in ecosystem service value per unit area.

3.2. Self-Consumption of ESV in Nujiang Prefecture

The water footprint was initially proposed on the basis of ecological footprint and virtual water [51], which indicates the amount of water resources needed for social production and consumption of all resources. It reflects the actual regional consumption of water resources in terms of consumption [52]. Similar to the ecological footprint [53], the water footprint can also quantify the extent to which human beings occupy natural resource capital [54]. As a result, we chose the water footprint model to measure the self-consumption of ecosystem services in Nujiang Prefecture. In the evaluation of the water footprint, the following four types of water requirements were mainly considered [45,46]: (1) water for agriculture, which specifically included crop and animal production water; (2) water for industry, which can be divided into industrial production, construction, etc.; (3) water for human life, which mainly included water used by residents for daily cooking, laundry, etc.; and (4) water for ecology, which primarily referred to water use for greenery and clean sanitization, etc.

The agricultural sector consumes the most water all over the world [55]. Various types of agricultural products actually contain a large amount of virtual water [56]. According to the social and economic situation of the Nujiang Prefecture, we selected ten main crops of wheat, rice, corn, barley, soybeans, oil crops, sugar crops, tobacco leaves, and vegetables, and five main animal products of pork, beef, mutton, eggs, and milk for the study. The factors that affect crop-water requirements include crop species, soil conditions, climate and irrigation methods, etc. Using Formulas (5) and (6), we can obtain the crop-water requirement ET_c and the unit virtual water content. The virtual water content of animal products refers to the virtual water content per unit product of Chinese animal products compiled by Chapagain and Hoekstra [52]. Given the wide variety of industrial products and their low virtual water consumption, the virtual water content of industrial products is often ignored and instead counted based on their actual water consumption. The actual water consumption data of water for industry, life, and ecology were obtained from the Water Resources Bulletin for each year. Then, we obtained the water footprint for Nujiang Prefecture from 2005 to 2020 based on the water footprint model presented above, as detailed in Table 3.

As far as individual crops are concerned, oil crops, tobacco leaves, and soybeans had higher virtual water contents per unit, indicating that these three crops needed more water during their growth. The crops that consumed lower virtual water content were potatoes, sugar crops, and vegetables. As far as water use sectors are concerned, agriculture consistently accounted for the largest proportion of virtual water use, all above 50%, with 64.68%, 55.60%, 55.64%, and 53.29% from 2005 to 2020, respectively. The water for industry and life first increased and then decreased, while water for ecology showed an upward trend from year to year. The water footprints of Nujiang Prefecture from 2005 to 2020 were 267.77×10^6 , 332.75×10^6 , 338.73×10^6 , and 326.20×10^6 m³. Overall, there was an upward trend in 2005–2015 and a significant decline in 2015–2020. This shows that from 2005 to 2015, people have a higher demand for material production and ecological

environment (an increase in industrial and ecological water use) with the development of society. In contrast, the 2015–2020 period showed a downward trend, mainly caused by lower water use in agriculture and industry. The reasons for this are as follows: on the one hand, in order to protect the ecology, the Nujiang Prefecture actively promotes the ecological management of steep slopes and implements the Returning Farmland to Forests project, with all steep slopes above 25 degrees in the prefecture requested to withdraw from farmland, resulting in a decrease in crop yield and eventually causing a decrease in water for agriculture; on the other hand, because of a certain time lag in the policy, some high-water-consuming and high-polluting industrial enterprises are gradually closed down only after a certain time following the introduction of the ecological protection policy. In addition, the Negative List of Industrial Access to National Key Ecological Function Areas introduced in Yunnan Province in 2018 also imposes controls and restrictions on industrial enterprises and higher environmental requirements, which eventually leads to lower industrial water use.

Table 3. Water footprint of Nujiang Prefecture in 2005–2020.

Items			Virtual Water /(m ³ ·kg ^{−1})	Consumption/×10 ⁶ m ³			
				2005	2010	2015	2020
Water for agriculture	Agriculture product	Wheat	1.36	18.20	10.20	15.45	11.43
		Rice	0.65	23.51	25.50	25.34	14.37
		Corn	0.63	47.62	57.55	60.60	51.08
		Barley	1.61	17.32	15.92	19.04	11.91
		Soybeans	1.94	30.98	34.60	38.67	31.70
		Potatoes	0.19	11.28	11.02	22.76	23.56
		Oil crops	3.95	2.88	5.58	7.90	4.46
		Sugar crops	0.10	6.70	7.68	7.91	1.31
		Vegetables	0.23	14.69	16.98	18.61	21.12
		Tobacco leaves	2.23	0.00	0.00	0.00	0.21
	Livestock product	Pork	2.21	39.50	53.00	57.81	65.86
		Beef	12.56	24.7	38.17	50.34	33.91
		Mutton	5.20	12.90	17.74	20.46	22.88
		Eggs	3.55	0.96	0.94	1.42	1.50
		Milk	1.00	0.19	0.17	0.41	0.36
Water for industry	-	-	-	7.65	22.94	21.00	7.15
Water for human life	-	-	-	8.36	14.17	18.00	13.96
Water for ecology	-	-	-	0.31	0.61	3.00	6.75
Total water footprint	-	-	-	267.77	332.75	388.73	326.20
Water availability	-	-	-	6497.10	4569.00	4317.00	6669.00

The water consumption coefficient, derived from the ratio of water footprint to water availability, was 4.12%, 7.28%, 9.00%, and 4.89% from 2005 to 2020, respectively, indicating that there were spillovers in the ecosystem service value of Nujiang Prefecture. Using the regional statistical yearbook data, we obtained the Engel coefficients from 2005 to 2020 of 0.45, 0.43, 0.32, and 0.30, respectively. Then, according to Formula (9), the upper limits of eco-compensation standards from 2005 to 2020 are CNY 120.01×10^2 million, CNY 128.25×10^2 million, CNY 197.12×10^2 million, and CNY 227.52×10^2 million (Table 4).

Table 4. Upper limit of eco-compensation standard based on ESV.

Year	ESV /×CNY 10 ² Million	Consumption Factor/%	Correction Factor/%	Upper Limit /×CNY 10 ² Million
2005	400.54	4.12	31.25	120.01
2010	407.29	7.28	33.96	128.25
2015	407.17	9.00	53.20	197.12
2020	408.36	4.89	58.58	227.52

3.3. Opportunity Cost of Ecological Protection in Nujiang Prefecture

Although the National Key Ecological Function Areas policy has been implemented since 2010, we also assessed the opportunity cost from 2005 to 2020 to facilitate comparison with the upper limit of the ecosystem-service-value method. Meanwhile, we took into account the impact of the establishment of the Three Parallel Rivers world natural heritage protection, and the Gaoligong Mountain National Nature Reserve. When selecting the reference area, the following principles were followed: (1) adjacent to the study area, to minimize the interference of geographical spatial heterogeneity factors; (2) non-“key ecological function zone”, which means that the reference area is not affected by the ecological compensation policy and has good development opportunities. Based on these two principles, Baoshan City and Lijiang City were selected as the reference areas for Nujiang Prefecture. We reduced uncertainties with the average opportunity cost of two reference areas. Finally, based on data obtained from the National Economic and Social Development Bulletin and formula (10) of each year, the opportunity costs were CNY 6.17×10^2 million, CNY 10.02×10^2 million, CNY 30.34×10^2 million, and CNY 41.97×10^2 million from 2005 to 2020, respectively. It is clear that Nujiang Prefecture has lost out on numerous types of growth prospects as a result of the restrictions placed on it by ecological preservation policies, and this opportunity cost is rising. The passion for ecological protection of Nujiang Prefecture will be diminished if there is a persistent absence of rational ecological compensation criteria, which is not helpful for the long-term growth of ecological protection mechanisms.

3.4. Rational Range of Eco-Compensation Standard in Nujiang Prefecture

Taking the ecosystem service values and opportunity costs derived from the equivalent factor method and the market comparison approach as the basis, we collated the upper and lower limits of eco-compensation in Table 5. It can be observed that the compensation standard is between CNY 6.17×10^2 million and CNY 227.52×10^2 million, which is a considerable difference. In addition, the upper and lower limits of the compensation standard increased synchronously. On the one hand, with the improvement of residents' living standards, their awareness of ecological protection also increased, and they were more willing to pay for ecosystem services [48,49]. On the other hand, due to the limitations resulting from ecological protection policy, the gap between local industry and resident life is growing compared with the reference area, which leads to an increase in the lower limits of the compensation standard.

Table 5. Eco-compensation standards of Nujiang Prefecture from 2005 to 2020.

Year	Upper Limit/×CNY 10 ² Million	Lower Limit/×CNY 10 ² Million
2005	120.01	6.17
2010	128.25	10.02
2015	197.12	30.34
2020	227.52	41.97

4. Discussion

4.1. Advantages and Uncertainties of Eco-Compensation Standards Recommended by This Study

The current study combined the ESVs and opportunity costs in recognizing both the ecological contribution of Nujiang Prefecture to the Nujiang Watershed and the economic sacrifices it makes for ecological conversation. This avoided the problem of disproportionate inputs to ecological outputs when applying the cost approach alone and low operability due to the high compensation standard when using the ecosystem-service-value method alone. The compensation standards of this study were neither so low as to harm the enthusiasm of ecological protection, nor so high as to be unable to afford. Based on the equivalent factor method, we observed that the ESVs of Nujiang Prefecture tend to stability after rising from 2005 to 2020. In contrast, land urbanization occurring in most regions of China was accompanied by the decrease in ecosystem service value [57], and the ESVs in urban agglomeration in the central Yunnan Province also declined from 2000 to 2020 [58]. This shows that the ecological protection of Nujiang Prefecture is quite effective, and the national key ecological functional zone policy and eco-compensation policy have played a positive role to some extent. From 2014 to 2020, Nujiang Prefecture has accumulated CNY 26.31×10^2 million of transfer payment funds issued by the central government for the key ecological function zone, with an average of CNY 4.78×10^2 million per year. Compared to the results obtained by the current study, it was observed that the current eco-compensation standard was unreasonable, which is also in line with Li et al.'s research results [34]. Meanwhile, the results of this study are in the same order of magnitude as that of Li et al.'s study on the Sichuan-Yunnan ecological barrier [59] and Chen et al.'s research on southwestern China [60]. The difference was mainly due to the different parameter settings of the equivalent factor method and the consideration of the willingness to pay. It suggests that the research results are scientific and can provide a reference for similar areas.

The uncertainties of the current study are mainly reflected in the following aspects. To begin with, the study used meteorological data obtained from the CLIMWAT 2.0 database recommended by FAO to measure water requirements when estimating the water footprint and only considered major agricultural products, which inevitably led to uncertainties. More detailed socio-economic, meteorological, and crop-growth data will make the water footprint calculation more accurate. Secondly, we chose a market comparison method with lower data requirements to estimate the opportunity cost of Nujiang Prefecture. Different understandings of opportunity costs will lead to significant differences in the compensation standards calculated by this method. In the future, it is possible to conduct in-depth research on the local reality and more comprehensively evaluate the opportunity cost of Nujiang Prefecture to protect the ecology. Finally, the eco-compensation standards obtained in this study were only a theoretical reference range, and did not take into account the functions of government intervention and gaming. The eco-compensation standard is negotiated between upstream and downstream governments. The amount of compensation is related to the negotiation ability of upstream and downstream governments and the coordination of the government. Therefore, the relationship between the negotiation ability of upstream and downstream governments and the amount of compensation is the focus of further research.

4.2. Policy Recommendations

Introduce the market mechanism to solve the problem of funding sources. At present, the ecological compensation in Nujiang Prefecture is basically a vertical transfer payment from the central to local government, which is highly dependent on the central government's finance. Simultaneously, it also caused a considerable burden to the central government [21]. Therefore, we can introduce a market mechanism based on vertical transfer payments. To improve the operability of eco-compensation standards, the upstream and downstream governments of the river basin can jointly fund the establishment of an ecological protection fund. On the one hand, the reasonable range of eco-compensation standards recommended in the current study can be used as a basis; on the other hand, environmental

monitoring can be strengthened. The results of the ecological environment assessment can be incorporated into the eco-compensation system, and the eco-compensation funds were adjusted within the rational range through intergovernmental negotiation to promote the smooth implementation of inter-regional eco-compensation.

Allocate and utilize eco-compensation funds to reasonably coordinate the interests of different parties. The eco-compensation policy is considered as an effective tool to solve the poverty problem in ecologically fragile areas, which can coordinate the dual goals of poverty alleviation and ecological protection [61,62]. In China, there is a high degree of geographic overlap between underdeveloped areas and key ecological functional zones [63]. As one of its typical representatives, Nujiang Prefecture coexists with abundant ecological resources and underdevelopment, and the contradiction between economic development and ecological protection is prominent [64]. From 2015 to 2020, Nujiang Prefecture implemented the poverty alleviation resettlement (PAR) policy, and about 100,000 people left the original, remote, and underdeveloped living environment through relocation. Among them were the Lisu, Yi, Dai, and other ethnic minorities. Their traditional ideology is deeply rooted, and it is difficult for them to integrate into the new environment in the short term. The previous self-sufficiency mode of life has been broken, causing them to face a greater risk of returning to poverty. Therefore, the eco-compensation policy of Nujiang Prefecture should be combined with the goal of poverty alleviation. Meanwhile, according to the principle of “whoever protects, who benefits”, we selected the stakeholders directly related to the land for distribution: the government, land operators, and residents. Therefore, to better consolidate the achievements of poverty alleviation, we assumed that the distribution ratio of the three was 7:1:2.

Taking the year 2020 as an example, we estimated that the rational range of eco-compensation in the Nujiang Prefecture was CNY 41.97×10^2 million to CNY 227.52×10^2 million. Therefore, the government, land operators, and residents will receive CNY 29.38×10^2 million to CNY 159.26×10^2 million, CNY 4.20×10^2 million to CNY 22.75×10^2 million, and CNY 8.39×10^2 million to 45.50×10^2 million, respectively. (1) The amount of ecological compensation obtained by the government accounted for 13.93–75.59% of GDP in 2020, which can be better used for people’s livelihood projects and ecological construction. First, the government can support characteristic industries, such as tourism and spice industries. We can attract local people to get jobs by building a characteristic industrial system in multi-ethnic areas. While retaining the national characteristics, it broadened its income-increasing channels. It can increase the public’s sense of participation and improve their awareness of ecological protection. The combination of multiple ecological compensation methods has far-reaching significance for regional sustainable development [65]. Second, the government can use this part of the funds to conduct publicity and education on ecological protection. There is a critical link between how farmers run their farms and what ecosystem services they value [66]. Therefore, it is necessary to guide residents to understand that ecological protection and economic development are not absolute conflicts, and a good ecological environment is a basis for economic development. (2) Subsidies to land operators can promote local land transfer. On the one hand, for farmers who have lost their source of income due to the inconvenience of moving back to their original place of residence, they can obtain land transfer income; on the other hand, for land operators, this part of ecological compensation funds can be used to relieve certain economic pressure, invest more in the field, improve land intensive use, and have a positive impact on the ecological environment. (3) After the compensation funds are distributed to residents in proportion, each person will receive at least CNY 1517.18 on average, accounting for 19.43% of the per capita disposable income of rural residents and 33.92% of the national poverty line of about CNY 4000 in 2020. It can prevent a large-scale regional return to poverty to a certain extent.

5. Conclusions

Taking the ecosystem-service-value method and opportunity cost method as the basis, the current study examined the rational range of eco-compensation standards for Nujiang Prefecture from 2005 to 2020. Firstly, we used the equivalent factor approach to assess the ESV. According to the externality theory, the water footprint model was used to evaluate its self-consumption of ESV. The upper limit of the eco-compensation standard was determined by combining the spillover value of ecosystem services with the Pearl curve. Secondly, we used the opportunity cost method to compare the Nujiang Prefecture with Baoshan City and Lijiang City, the reference areas. We ultimately calculated the opportunity cost and the lower limit of eco-compensation standard at the government and resident levels. Our results suggest that:

(1) The ecological protection of Nujiang Prefecture has been remarkable. Its ecosystem service value increased from $\text{CNY } 400.54 \times 10^2$ million in 2005 to $\text{CNY } 408.36 \times 10^2$ million in 2020. Regarding the service content, Nujiang Prefecture mainly provided regulation and support services among the primary types of ecosystem services. Among the secondary types, climate regulation, hydrological regulation, and soil conservation were its core functions.

(2) There was an ecological value spillover from Nujiang Prefecture. Its self-consumption factor declined after increasing from 4.12% in 2005 to 9.00% in 2015. This decline was due to ecological protection policies, such as the Returning Farmland to Forests project, which restricts agricultural production and industrial enterprise development, resulting in lower agricultural virtual water and industrial water use.

(3) Whether from the perspective of opportunity cost or ecosystem service supply, Nujiang Prefecture should receive eco-compensation. The rational ranges of compensation standards were $\text{CNY } 6.17 \times 10^2$ million to 120.01×10^2 million in 2005, $\text{CNY } 10.02 \times 10^2$ million to 128.25×10^2 million in 2010, $\text{CNY } 30.34 \times 10^2$ million to 197.12×10^2 million in 2015, and $\text{CNY } 41.97 \times 10^2$ million to 227.52×10^2 million in 2020. The upper limit can be used as a reference for the eco-compensation standard, while the lower limit provides a bottom line for the eco-compensation standard of the study area.

The results of the current study contribute to the recognition of ecosystem-service-value spillover and a fair understanding of the ecological contribution of the study area, and also help to recognize the opportunity cost of the study area. They provide suggestions for a reasonable range of compensation standards, and help decision makers design eco-compensation projects. Meanwhile, this study can provide a reference for similar areas to help their ecological conservation and sustainable development.

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