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Eco-Compensation Mechanism Construction of Chongyi Hakka Terrace Ecosystem

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Abstract. Chongyi Hakka Terrace is located in Chongyi County in the south of Jiangxi Province, which is the largest Hakka Terrace in China. As a special agricultural ecosystem, it provides many ecological services for the Hakkas in Chongyi County. In recent years, with the increase in the opportunity cost of rural labor output, the abandonment of Chongyi Hakka terraces is becoming more and more serious, and the sustainable development of its ecosystem is facing severe challenges. Therefore, it is necessary to build a reasonable ecological compensation mechanism to promote farmers' protection of the terrace ecosystem in the Chongyi Hakka Terrace area. In this paper, the problems existing in the Chongyi Hakka Terrace ecosystem are analyzed, and the externality of economic benefits and the subject and object of ecological compensation of the Chongyi Hakka Terrace ecosystem are identified. Based on this, combined with the existing research results, the ecological compensation standard of the Chongyi Hakka Terrace system is formulated, the government should provide 6.58×10^8 RMB·per year to farmers in the large-scale contiguous area of Chongyi Hakka Terrace. The priority of ecological compensation of the three townships in the large-scale contiguous area is Sishun Township, Fengzhou Township, and Shangbao Township. At the last, the implementation system of ecological compensation for the Chongyi Hakka Terrace system is proposed, for the purposes of providing a reference for government departments to formulate sustainable management countermeasures for the Chongyi Hakka Terrace ecosystem.

Keywords. Chongyi Hakka Terrace ecosystem, China National Important Agricultural Heritage System, economic externality, eco-compensation criterion, eco-compensation mechanism

1. Introduction

Eco-compensation is a policy measure that utilizes economic means to regulate the

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interests of stakeholders in the ecosystem to achieve sustainable utilization of ecosystem service functions [1]. Its purpose is to punish negative effects on resources and the environment, reduce external diseconomies, compensate for positive effects on resource protection, and promote sustainable development of ecological resources. The construction of ecological compensation mechanism specifically includes the externality of economic benefits, the cognition of compensation subject and object, and the formulation of eco-compensation standards and the compensation sustainable system, among which the determination of eco-compensation standards is the core issue [2-4]. The implementation of eco-compensation is conducive to adjusting the distribution relationship of ecological and economic benefits among relevant stakeholders, and promoting ecologically fragile areas and important ecological functional areas to assume important responsibilities for protecting ecology [5]. At present, eco-compensation has been widely practiced and recognized internationally, becoming an important means of protecting natural resources and the ecological environment, and a hot research topic in the field of international ecological economics [6-8]. However, most studies have focused on large ecosystems such as forests [9], grasslands [10], watersheds [11], lakes [12], and oceans [13], and there are few mechanisms for eco-compensation in terraced systems.

Terraced fields are fields constructed by ancient working people in mountainous areas along contour lines in order to alleviate land resource shortages. It is the best way for humans not only to fully utilize mountain resources to obtain agricultural products but also to preserve water and soil moisture [14]. The Chongyi Hakka terraced fields are located in Chongyi County, Jiangxi Province, China, with a total area of 3000 hectares and a history of over 800 years of agricultural cultivation. They are a model for the ancestors of the Chongyi Hakka to utilize and respect nature [15]. As a Globally Important Agricultural Heritage System [16], the Chongyi Hakka Terrace ecosystem contains important historical and cultural values, scientific research values, ecological values and economic values. It is necessary to carry out effective eco-compensation for them from the perspective of sustainable development. The necessity of implementing eco-compensation for the Chongyi Hakka Terrace ecosystem is mainly manifested in three aspects. Firstly, with the impact of agricultural modernization and rural urbanization on traditional agricultural production, it is required that public finance must provide sufficient financial support for the protection of traditional agricultural culture in the Chongyi Hakka Terrace ecosystem. Secondly, as a carrier for inheriting traditional agricultural culture, the Chongyi Hakka terraced field system should prioritize biodiversity conservation and reduce abandoned terraced fields. The government should restrict intensive agriculture with a large amount of pesticide and fertilizer input and a single variety, and guide farmers to sow in a timely manner. This will to some extent result in a relatively low local agricultural output rate and a decrease in the absolute returns of farmers. The protection of traditional agricultural culture involves high direct and indirect costs, which require appropriate transfer payment fees to compensate. Finally, the Chongyi Hakka Terrace system contains the attributes of public goods and has external economic effects. Therefore, economic compensation must be provided for the losses and costs incurred by the terraced field system in activities related to the protection of traditional agricultural culture, in order to internalize the external economic effects of the terraced field system. The eco-compensation mechanism of the Chongyi Hakka Terrace system should be guided by "Globally Important Agricultural Heritage Systems", based on the ecological service function value of the Chongyi Hakka Terrace system, combined with the ownership of

land, and follow the basic principle of "users and beneficiaries pay, protectors get compensation".

2. Data and Analysis Software

2.1. Data Source

The data mainly comes from two on-site investigations in December 2014 and March 2016, as well as telephone interviews in October 2021. Some references are made to the "Chongyi County Statistical Yearbook", "Jiangxi Chongyi Hakka Terrace System Protection and Development Plan", "Chongyi County and Core Area Land Use Types Area", "China Statistical Yearbook", and previous research results.

The large-scale contiguous area of Chongyi Hakka terraced fields is located in three townships: Shangbao, Sishun, and Fengzhou, involving 26 administrative villages, with an area of 2044 hm^2. The core area is located in Shangbao Township, involving 10 villages, with a total of 1491.13 hm^2 of terraced fields. For the convenience of research, this paper focuses on the large-scale contiguous areas of Hakka terraces when discussing the amount of regional ecological compensation.

2.2. Analysis Software

The analysis software adopts Excel 2010 and Matlab R2012A.

3. Framework of Eco-compensation Standards for Chongyi Hakka Terrace System

3.1. Externality of Chongyi Hakka Terrace System

Externality refers to the behavior of producers (or consumers) to other consumers (or producers) beyond the scope of the subject in actual economic activities, but this behavior does not appear in market prices [17]. When the behavior of the subject benefits the other party, it manifests as a positive external economic effect. As the behavior of the subject causes damage to the other party, it manifests as negative external economic benefits. The positive externality of the Chongyi Hakka Terrace system is mainly reflected in the fact that it provides people with the cognition of traditional agricultural culture (cognitive value, scientific research value), maintains biodiversity (ecological value), and gives people visual enjoyment (economic value, demonstration value) by protecting the Hakka Terrace system. Negative externality refers to the low profit of the traditional planting industry in the Chongyi Hakka terraced field system, which intensifies labor transfer, resulting in land abandonment, a sharp reduction of traditional germplasm resources, and the gradual disappearance of agricultural cultural heritage.

3.2. Eco-compensation Framework for Chongyi Hakka Terrace System

In theory, farmland eco-compensation refers to the spillover of ecological service value from the beneficiaries of farmland ecology to all farmland within the research area [18].

The compensation for the Chongyi Hakka Terrace ecosystem is mainly relied on the paid use of terraced fields, through administrative intervention by government agencies, giving ecological punishment to those who cause damage to the ecological structure of the terraced field system, and promoting regional fair development. By analyzing the ecological service value of the Chongyi Hakka Terrace ecosystem, the loss of ecological service value of abandoned farmland, and the number of labor resources required for abandoned farmland, the profit and loss of the terrace system are calculated. Based on existing research results [18-20], the eco-compensation framework of the Chongyi Hakka Terrace ecosystem is shown in Figure 1.

In Figure 1, when the large-scale contiguous area of Chongyi Hakka terraces reduces labor loss and the total ecological value generated by land cultivation is positive after subtracting the direct value of the ecosystem, the income difference between developed and local human capital, and the government's subsidies for agricultural planting, the ecological surplus of the large-scale contiguous area of Chongyi Hakka terraces appears, making contributions to the country. On the contrary, if the scale of the Chongyi Hakka Terrace ecosystem continues to drain rural labor from the area to other areas, the Chongyi Hakka Terrace ecosystem will lose a series of original values due to inadequate development, making other areas unable to enjoy these values, and therefore, in a state of ecological and economic deficiency.

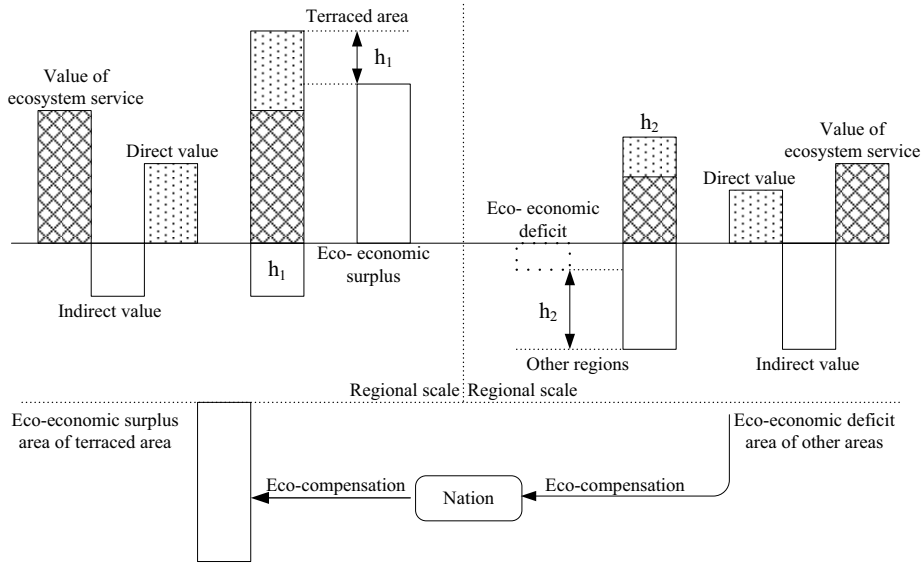

Figure 1. Eco-compensation framework of Chongyi Hakka Terrace system.

3.3. Accounting Method for Eco-compensation Standards

The eco-compensation standard refers to the amount of eco-compensation [7], and developing appropriate compensation standards can effectively promote the implementation of compensation mechanisms [21]. At present, there is no unified model for the determination of eco-compensation standards by domestic and foreign scholars, and there are obvious differences in the research on eco-compensation

standards [22]. The academic circles usually calculate the eco-compensation standard by referring to the regional comparison, the total cost of ecological protection, the value of ecological service function and the willingness to pay method.

Based on the economic externality and accounting framework of the Chongyi Hakka Terrace system, and based on the ecological service value of the terrace system per unit area, the paper constructs models (1) and (2) to determine the eco-compensation standards and priorities.

$$E_c=E_t+I_p-I_g \tag{1}$$

$$E_f=A_i/A \tag{2}$$

In the equation, E_c and E_f respectively represent the eco-compensation standards and priorities of the Chongyi Hakka Terrace system, while E_t, I_p, I_g, A_i, and A respectively represent the indirect value of the ecological service function of the terrace system as Table 1, the total income difference of labor force, government subsidies, the *i-th* region's abandoned area of terraces, and the total abandoned area of terraces [23]. Among them, I_p and I_g are calculated using the following model.

$$I_p=(S_d-S_r)\times N_c \tag{3}$$

$$I_g=M_c\times A \tag{4}$$

Table 1. Service value of Chongyi Hakka Terrace system.

Type of value	Service indices	Values per hectare (RMB·hm^{-2})
Direct value	Reducing unemployment	0.25
	Material provision	3.60
Indirect value	Gas regulation	1.78
	Adjusting water resources	0.83
	Soil conservation	10.67
	Environmental purification	0.80
	Wildlife habitats	0.15
	Insects & Weeds control	3.37
	Travel & Leisure	4.63
	Cultural transmission	10.00
Total	-	36.08

Note: The data is sourced from Reference [16].

In the equation, S_d and S_r refer to the average monthly income of the rural labor force working in economically developed areas and engaging in the planting industry at home. They are taken as the average of the first tier of the minimum wage standard in Beijing, Shanghai, and Guangzhou in 2021 (2403 RMB per month and person) and the net per capita planting industry income in the large-scale contiguous area of Chongyi Hakka Terrace ecosystem in 2020 (1155 RMB per month and person), respectively. N_c represents the amount of labor required to cultivate abandoned farmland, with each labor force capable of cultivating 0.4 hm^2 in the hills of Qiaogang, resulting in N_c=629 people. M_c provides subsidies for the planting industry to the government, based on the 2020 national subsidy standard of 3450 RMB•hm^{-2} for major grain farmers.

4. Implementation Measures for Eco-compensation Mechanism of Chongyi Hakka Terrace System

4.1. Eco-compensation Amount

According to equation (1), the eco-compensation amount for the Chongyi Hakka Terrace system is calculated in Table 2. According to Table 2, Qiyunshan Village received the highest ecological subsidy of 1.49×10^8 RMB, while Shuinan Village received the lowest subsidy of 0.09×10^8 RMB. The eco-compensation amounts for Shangbao, Sishun, and Fengzhou townships are 1.35×10^8, 2.98×10^8, and 2.25×10^8 RMB, respectively.

Table 2. Eco-compensation standards for Chongyi Hakka Terrace system.

Villages and towns	Natural village	E_c ($\times10^8$ RMB)
Shangbao	Shangbao Village	0.16
	Chishui Village	0.14
	Shuinan Village	0.09
	Zhuxi Village	0.19
	Jiazi Village	0.15
	Nuanshui Village	0.19
	Junyuan Village	0.28
	Meikeng Village	0.15
Sishun	Qiyunshan Village	1.49
	Xindi Village	1.12
	Changjiang Village	0.37
Fengzhou	Xiaokeng Village	0.48
	Baishi Village	0.41
	Jiuling Village	0.37
	Yanhu Village	0.28
	Oujia Village	0.71
Total	-	6.58

4.2. Eco-compensation Priority Index

The eco-compensation priority index of the Chongyi Hakka Terrace system is calculated with equation (2). The eco-compensation priority of the Chongyi Hakka Terrace system is ranked by natural villages as Figure 2: Qiyunshan village, Xindi village, Oujia village, Xiaokeng village, Baishi village, Changjiang village, Jiuling village, Yanhu village, Junyuan village, Zhuxi village, Nuanshui village, Shangbao village, Jiazi village, Meikeng village, Chishui village, and Shuinan village. The priority of ecological compensation is ranked by the township in Figure 3, Sishun villages, Fengzhou villages, and Shangbao villages.

4.3. Eco-compensation Promotion

Eco-compensation is a new concept. For the government, in order to achieve the expected effect of economic compensation, it is necessary to strengthen publicity and education related to farmers, and make them clear that the Chongyi Hakka terraced

ecosystem has both direct value functions such as alleviating unemployment and product supply, as well as indirect value functions such as gas regulation, water resource regulation, soil conservation, environmental purification, biodiversity, pest control, landscape, culture, etc. It can provide them with a direct economic value of approximately 3.8×10^4 RMB · hm^{-2} and an indirect economic value of 3.2×10^5 RMB · hm^{-2}. While providing ecological and economic compensation to local farmers, The government ought to teach them environment-friendly green agriculture production technology, ways to effectively protect traditional agricultural culture, and methods to reasonably develop terrace tourism resources. Meanwhile, the government must require the local farmers to consciously stop their behavior of damaging the Chongyi Hakka Terrace ecosystem, to protect the composite structure of the Chongyi Hakka Terrace ecosystem, and to consciously serve the Chongyi Hakka Terrace ecosystem. For other social public, it is also necessary to let them know clearly that the Chongyi Hakka terraces can fix CO_2 1.1×10^4 kg · hm^{-2}, release O_2 8.1×10^3 kg · hm^{-2}, conserve water 5.3×10^3 kg · hm^{-2}, maintain soil fertility 7.6×10^4 kg · hm^{-2}, contain landscape value 4.6×10^4 RMB · hm^{-2} and cultural inheritance value 3.0×10^4 RMB · hm^{-2} [16], which has rich ecological and economic value. Thus, they are also willing to contribute to the protection of the Hakka Terrace ecosystem in Chongyi. For the government, it is important to make them aware that ecological compensation for the Hakka Terrace ecosystem can promote the rapid development of local society, economy, culture, and ecology.

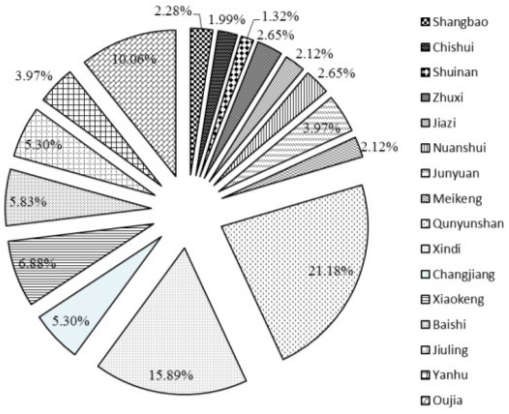

Figure 2. Priority of eco-compensation for various natural villages in the Chongyi Hakka Terrace system.

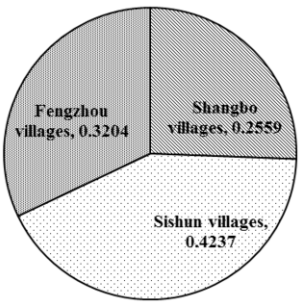

Figure 3. Priority of eco-compensation in the core area of the Chongyi Hakka Terrace system.

4.4. Compensation System Development

The eco-compensation of the Chongyi Hakka Terrace system is a special case of agricultural eco-compensation. When designing compensation policies for them, the government should have clear and clear objectives [23], so that eco-compensation policies mainly focus on the protection and construction of the Hakka Terrace system in Chongyi. Governments at all levels should take the initiative and actively carry out legislative work on the eco-compensation mechanism for the Hakka terraced field system in Chongyi, formulate ecological compensation rules and regulations, clarify

the subjects, objects, scope, standards, etc. of eco-compensation, and clarify the rights and obligations of relevant stakeholders. Specifically, it includes, firstly, the government implementing financial incentives, agricultural subsidies, and other measures for farmers planting terraced fields. Compensation measures can refer to national agricultural support subsidies, and the subsidy period is until the planned deadline. Punitive collection of idle fees for abandoned farmers in accordance with relevant laws and regulations. Those who have abandoned farmland and abandoned land for two consecutive years shall terminate their contractual rights and reclaim their contracted land. Secondly, it should be determined that the government needs to reasonably bear the cost of protecting the traditional agricultural culture of the Chongyi Hakka Terrace ecosystem. Using the indirect value of ecosystem service functions minus the total income difference of labor and planting subsidies as the compensation threshold, the government must compensate 6.58×10^8 RMB annually to the Hakka Terrace ecosystem protectors in Chongyi. Thirdly, Expanding compensation channels, such as utilizing financial assistance from the Food and Agriculture Organization of the United Nations, national policy support, and regional ecological advantages, vigorously developing "hematopoietic" project compensation forms such as selenium rich organic agriculture and ecotourism, forming an industrial chain with high-end and high-quality agricultural product production, processing, transportation, and sales services, improving the development capacity of the Hakka Terrace ecosystem industry in Chongyi, and promoting its sustainable development.

5. Conclusion

The Chongyi Hakka Terrace ecosystem, as a special agricultural ecosystem, has important ecological service value in soil and water resource conservation, regional environmental regulation, biodiversity maintenance, leisure tourism, and other aspects. In recent years, due to the increase in the opportunity cost of working as a migrant worker, the phenomenon of abandoned terraced fields has emerged one after another, seriously threatening the positive service value output of its ecosystem. Therefore, the construction of ecological compensation mechanism is of great significance to the protection of the ecosystem service function of Chongyi Hakka terraced fields and the encouragement of positive externality of farmers' production behavior in Chongyi Hakka terraced fields. Based on the ecological service value of the Chongyi Hakka Terrace system, combined with the opportunity cost of labor output and the government's planting subsidies, this study calculates the ecological compensation standards and compensation priorities of each natural village in the large-scale connected area of the Chongyi Hakka terrace. Each natural village receives subsidies in order of size: Qiyunshan village, Xindi village, Oujia village, Xiaokeng village, Baishi village, Changjiang village, Jiuling village, Yanhu village, Junyuan village, Zhuxi village, Nuanshui village, Shangbao village, Jiazi village, Meikeng village, Chishui village, Shuinan village. The eco-compensation amount for the three townships is in the order of size: Sishun Township, Fengzhou Township, and Shangbao Township. The eco-compensation priority index in Qiyunshan village is the highest at 0.21, while the lowest in Shuinan village is 0.13. The ecological priority compensation index of the three townships is the highest in Sishun Township and the lowest in Shangbao Township.

The establishment of an eco-compensation mechanism is a complex system engineering that involves scientific evaluation of the value of ecosystem service functions, effective protection of regional resources and ecology, and the formulation of eco-compensation strategies and measures in accordance with the law. Especially in the Chongyi Hakka Terrace ecosystem, the eco-compensation mechanism cannot be simply attributed to food production, but also needs to comprehensively consider aspects such as terrace germplasm resources, ecological environment, regional economic development, traditional agricultural culture, and terrace landscape. Therefore, the ecological compensation mechanism of the Chongyi Hakka Terrace system is a relatively complex research topic. When designing the eco-compensation mechanism, we need to clarify its connotation and key issues, such as economic externality, value accounting method, compensation objects, standards, ways and methods, etc. Due to limitations in data and technology, this paper only considers the degradation area of regional terraces and does not consider the differences in regional ecological service functions in calculating the eco-compensation priority of the Chongyi Hakka Terrace system. This may have some deviation from the actual local situation. Taking into account the differences in regional ecological service functions, refining the subject and object of eco-compensation, and precise value accounting methods can help establish a more comprehensive eco-compensation mechanism for the Chongyi Hakka Terrace system.

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