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ECOLOGICAL COMPENSATION STANDARDS FOR PADDY FIELDS IN GUANGXI: PERSPECTIVES FROM RICE FARMERS

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Abstract
Low-carbon rice production technology is vital for safeguarding the ecological health of rice fields. However, the ecological benefits of such practices often fail to motivate rice farmers to adopt these low-carbon methods actively. In response, the Chinese State Council introduced the "Opinions on improving the compensation mechanism for ecological protection" in 2016, emphasizing the principle of "who protects, who benefits; who pollutes, who pays" for equity in ecological compensation. The key to driving rice farmers to protect paddy field ecosystems lies in establishing a fair and reasonable ecological compensation standard. While existing research on ecological compensation has examined subjects, standards, and methods, this study delves into the critical aspect of setting ecological compensation standards. In previous studies, scholars investigated various aspects, including the urban and rural population's perspective on farmland ecological compensation, the carbon measurement method to assess carbon sink function compensation, the calculation of ecological compensation standards for different regions, and diverse compensation methods such as government-based, market-based, tax, and fund-driven compensation.

Keywords: Low-carbon rice production, ecological compensation, compensation standards, paddy field ecosystems, ecological protection.

1. Introduction

Low-carbon rice production technology plays an important role in protecting the ecological environment of rice fields while the externality of ecological benefits of rice fields cannot encourage rice farmers to actively adopt rice low-carbon production technology to protect the ecological environment of rice fields. To encourage the public to participate in ecological protection, the State
Council issued the “Opinions on improving the compensation mechanism for ecological protection” in 2016, which clearly pointed out that ecological compensation should follow “who protects, who benefits; who pollutes, who pays.” for fairness. Thus, it can be seen that determining a reasonable ecological compensation standard is the key to encourage rice farmers to protect the ecological environment of paddy fields.

In the existing research on ecological compensation, most scholars focused on the compensation subject [1, 2], the compensation standard [3, 4], and the compensation method [5, 7]. In terms of compensation subjects, Cai et al. [1, 2] studied farmland ecological compensation from the perspective of urban and rural populations and consumer demand. In aspect of compensation standard measurement, Song et al. [8] used carbon measurement method to measure the ecological compensation standard of the carbon sink function of vegetables in facilities and the outcome is 21.37 yuan/mu. Yang et al. [9] calculated that the ecological compensation standard of farmland in Wuhan was

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7407.24 yuan/hm² based on the potential classification model of selection experiment. Li et al. [10] used the conditional value assessment method to estimate the ecological compensation standard of farmland in key ecological function areas in Hubei Province, which was 3017.10~3775.65 yuan/(hm²a·). Lv et al. [11] used the double-boundary dichotomous conditional value assessment method to estimate the ecological compensation standard of chemical fertilizer application control paddy in Lishui District of Nanjing City, which was 882.49 yuan/(hm²·a). Luan et al. [12] calculated based on utility theory that the ecological compensation standard for agricultural non-point source pollution control in the Dongting Lake Basin was 1640.20 yuan/hm². As to compensation methods, Yang [5], Zheng et al [6]believed that ecological compensation should be carried out through government compensation and market compensation. Pettinotti et al.[7]believed that eco-compensation should be done through taxes and funds.
This paper applies conditional valuation method and takes the survey data of 179 rice farmers in Guangxi as an example, and determine the ecological compensation standards for rice fields in
Guangxi from the perspective of rice farmers' willingness to pay. This paper also uses binary logistic model to analyze the influencing factors of rice farmers' willingness to pay and provides reference data for the establishment of ecological compensation mechanism in Guangxi.

2. Utility Theoretical analysis

Utility theory is the basis for rational economic customers' decision-making to maximize utility. Under uncertainty, the goal of rational economic customers' decision-making goal is to maximize his own utility, that is, to obtain the maximum degree of satisfaction rather than the maximum amount [13]. According to Hicks welfare measurement theory, compensation variation (CV) indicates the consumer's willingness to be compensated or paid when utility is consistent before and after price change [14]. The Hicks compensation function expression is as follows:
CV ⁼e⁼P,Q_1,U_1⁼⁼e⁼P,Q_0,U_0⁼
where P is the price of the commodity; Q_0 and Q_1 represent the ecological environment status of paddy fields before and after the implementation of the policy; U_0 is the initial utility of the individual before the implementation of the policy, and U_1 is the utility after the implementation of the policy. e(P,Q_1,U_1) stands for the monetary spending function, which indicates that consumers minimize spending in order to get the expected utility. The implementation of any resource and environmental policy will not only generate social benefits, but also bring social costs. As far as the rice ecological compensation policy is concerned, rice farmers participate in rice ecological environmental protection by reducing the application of chemical fertilizers and pesticides, and adopting low-carbon rice production technologies such as soil testing formula fertilizer and biological pesticides, which may reduce rice yield, thereby reducing the utility of rice farmers. As rational economic beings, rice farmers will only participate in policy if they have received at least an amount that can compensate for the reduction in utility. Therefore, in order to maintain the utility of rice farmers before and after the implementation of the policy, the government needs to pay rice farmers a "compensatory change (CV)"[13], that is, the willingness of rice farmers to be compensated can be expressed in compensatory variation (CV).

3. Methodology

3.1. Contingent valuation method

Conditional valuation method is a kind of stated preference evaluation method. With the help of questionnaires, farmers' willingness to receive compensation or willingness to pay for ecosystem service changes are investigated by constructing the simulated market of ecosystem public goods services [15]. The questionnaire adopts the form of interval estimation, and the median of the interval is taken as the payment standard of rice farmers. E_k (k = 1,2,3) represents the payment level of rice farmers, V_i represents the i th level selected by rice farmers, and P_i represents the probability of the i th level. The formula for calculating the payment level of rice farmers is as follows:
Ek ⁼⁼in ⁼1Pi ⁼Vi

3.2. Binary Logistic Model

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There are two options for rice farmers' willingness to pay: "willing" or "unwilling", as the explained variable y can be defined as a binary selection variable of 0 and 1. Hence binary logistic model was selected to analyze the influencing factors of rice farmers' willingness to pay. P_i be the probability that rice farmers chose "willing" and x_j be the explanatory variable, then λ_j is the parameter to be estimated corresponding to the explanatory variable, and ξ is constant term. The model was established as follows:

pi 1/ 1e nj1jxj

Using formula (3) to perform logarithmic transformation, and the linear expression of the binary Logistic model can be obtained as:

p i n x j y ln1p_i _____ j1j

4. Data sources

4.1. Design of questionnaire

The questionnaire is made up of three main parts: The first part is the cognition of rice farmers, mainly including ecological environment awareness, low-carbon production awareness and ecological compensation awareness. The second part is the willingness and level of payment of rice farmers. The third part is the basic information of rice farmers, mainly including personal characteristics, family characteristics and income.

In this paper, the conditional value assessment method is used to investigate the willingness of farmers to pay for rice field ecological protection. In the actual questionnaire, there are information biases and hypothetical biases in the payment quota of rice farmers asked through simulated market scenarios. In order to effectively reduce the bias, corresponding solutions were adopted in the design of the questionnaire. In the question regarding rice farmers' willingness to pay, respondents were asked, "Under realistic circumstances, in order to protect the ecological environment and the ecological benefits of rice fields, how much is your family willing to pay at most to protect one mu of rice fields per year?" If the survey respondents agree to compensate and are willing to pay the specified amount, the questionnaire uses a semi-closed format, presenting thirteen payment options: 0~50 yuan, 51~100 yuan, 101~150 yuan, 151~200 yuan, 201~250 yuan, 251~300 yuan, 301~350 yuan, 351~400 yuan, 401~450 yuan, 451~500 yuan, 501~550 yuan, 551~600 yuan, and 600 yuan or more. Secondly, the simulation scenarios are explained in each part of the questionnaire, and the connotations of specific questions and the terms that appear in them are succinctly supplemented.

4.2. Data acquisition

Table 1. Basic characteristics of interviewed rice farmers

Index	**Type**	**Num.**	**Frequency(%)**
Gender	female	41	22.91
	male	138	77.09
Education	No education	0	0
	Primary school	9	5.03
	junior high school	70	39.11
	High School/College	56	31.28
	Bachelor degree and above	44	24.58
Village cadre	Yes	30	16.76
	No	149	83.24

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Average age(years)	42.74
Average family income (10 thousand yuan/year)	3.88
Average household cultivated land area (mu)	10.86

From January to April 2021, the research group collected 232 rice farmers' questionnaires by means of online survey, 179 of which were effective, and the questionnaire efficiency was 77.16%.This paper uses SPSS 25.0 software to test the reliability and validity of the questionnaire. Among them, the
Cronbach's α coefficient is 0.912, indicating that the reliability of the questionnaire is very good. The KMO value of the validity test is 0.890, which is greater than 0.6. The P value of the Bartlett sphere test is 0.000, indicating that the rice farmer questionnaire has good validity.
The basic characteristics of the interviewed rice farmers are shown in Table 1, where males account for 77.09%. The rice farmers surveyed have a relatively low level of education, with 75.42% of them having a high school degree or below. Among them, 30 people serve as village cadres, accounting for 16.76%. The average age of the rice farmers interviewed is 42.74. The average annual income of the family is 38800 yuan. The average cultivated land area of rice farmers' families is 0.724 hectare.

4.3. Selection of variables

Combined with the existing research results [13, 14], this paper determines that the influencing factors of rice farmers' willingness to pay are individual characteristics, family characteristics, ecological compensation cognition, low-carbon production cognition and low-carbon technology adoption intention. The specific variable information is shown in Table 2.

Table 2. The influencing factors of rice farmers' willingness to pay

Variable name	**Variable assignment**	**Mean**	**Standard deviation**
Individual characteristics			
Gender	Gender of farmers: female=1; male=0	0.23	0.42
Age	Age of farmers(years)	42.74	10.97
Minority	Yao ethnic group=1; Zhuang ethnic group=2; Yao ethnic group=3; Miao ethnic group=4; Tong ethnic group=5; Mulao ethnic group=6; Others=7	1.46	1.15
Education	No education=1; Primary school=2; Junior high school=3; High School/College=4; Bachelor degree and above=5	3.75	0.88
Village cadre	Is it a village cadre: Yes=1; No=0	0.17	0.37
Family characteristics			
Annual family income (10 thousand	1 and below=1; 1<income≤2=2; 2<income≤4=3;	3.30	1.69

yuan/year)	4<income≤6=4; 6<income≤8=5; 8<income≤10=6		
Proportion of agricultural income	Below 20%=1; 21%~40%=2; 41%~60%=3; 61%~80%=4; above81%=5	3.07	1.37
Area of paddy field	Household rice field area (mu)	10.86	22.14
Ecological compensation cognition			
Degree of ecological compensation support	Very unsupported=1; Not very supportive=2; common=3; very supportive =4; strongly supportive=5	4.45	0.82
Subject of ecological protection responsibility	Unclear=1; government=2; agricultural enterprises or agricultural cooperatives=3; farmers=4; urban residents=5; all people=6	5.07	1.59
Ways of ecological compensation	Fund compensation=1; substantial compensation=2; policy compensation=3; intelligence compensation=4; others=5	2.16	1.22
Low-carbon production awareness			
Degree of environmental concern	Very unconcerned=1; not very concerned=2; common=3; very concerned=4; strongly concerned=5	3.89	1.15
Economic benefits	Totally disagree=1; not very agree=2; common=3; very agree =4; totally agree=5	3.66	1.25
High-quality green agricultural products	Totally disagree=1; not very agree=2; common=3; very agree =4; totally agree=5	4.25	0.92
Low-carbon production training	Whether participate: yes=1;no=0	0.26	0.44
Rice farmers' willingness			

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Willingness to adopt low-carbon technologies	Very unwilling=1; not very willing=2; common=3; very willing =4; strongly willing=5	3.20	1.18

5. Result analysis

5.1. Calculation results of compensation standard from the perspective of rice farmers

The frequency distribution of rice farmers' payment level is shown in Table 3. According to formula (2), the payment level for rice farmers to protect the ecological environment of paddy fields is 179.33 yuan/ (mu·year).

Table 3. Frequency distribution of rice farmers' payment level

Limit range	**Rice farmers' payment limit**	
	Times(Person times)	**Frequency(%)**
0	19	10.61
0~50	36	20.11
50~100	46	25.70
101~150	3	1.68
151~200	17	9.50
201~250	8	4.47
251~300	8	4.47
301~350	5	2.79
351~400	6	3.35
401~450	5	2.79
451~500	6	3.35
501~550	4	2.23
551~600	6	3.35
Above 600	10	5.59
CVM estimate	179.33 yuan/(mu·year)	

5.2. Analysis on Influencing Factors of rice farmers' willingness to pay

Table 4. Estimation results of binary logistic model

Variable name	**Regression coefficient**
Individual characteristics	
Gender	0.623
Age	-0.016
Nation	—
Education	-0.323
Village cadre	0.088
family characteristics	
Annual family income	0.071

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Proportion of agricultural income	0.429*
Area of paddy field	-0.017*
Ecological compensation cognition	
Degree of ecological compensation support	0.055
Subject of ecological protection responsibility	-0.057
Ways of ecological compensation	0.590**
Low-carbon production awareness	
Degree of environmental concern	0.479*
Economic benefits	-0.495
High-quality green agricultural products	0.961**
Low-carbon production training	1.418
Rice farmers' willingness	
Willingness to adopt low-carbon technologies	-0.040
Constant term	-2.698
Pseudo R^2	0.202
Prob>chi^2	0.058

a. ***, **, * means significant at the statistical level of 10%, 5% and 1% respectively.

Family characteristic variable. It can be seen from Table 4 that the proportion of agricultural income has passed the significance level test of 10%, and has a positive impact on the willingness to pay. The higher the proportion of agricultural income, the more single the income source of rice farmers. Rice field resources are a production factor, and rice farmers are more willing to carry out ecological protection of rice fields in order to achieve the purpose of sustainable use of it. The area of paddy field is significant at the 10% statistical level, and it negatively affects rice farmers' willingness to pay. The possible cause is that the smaller the area of paddy field, the less the total expenditure, and the more willing rice farmers are to pay for protecting the ecological environment of paddy field. The coefficients of individual characteristic variables are not significant.

Ecological compensation cognition. Ecological compensation has a significant positive impact on rice farmers' willingness to pay at the statistical level of 5%. It shows that the more rice farmers tend to intellectual compensation, the stronger their willingness to pay. The possible cause is that rice farmers have a low level of education as a whole, and it is difficult to understand and master low-carbon production technology. Therefore, they prefer to accept ecological compensation through intellectual compensation such as technical training.

Low-carbon production awareness. The degree of environmental concern has a significant positive impact on rice farmers' willingness to pay at the statistical level of 10%. The higher the degree of environmental concern, the stronger the rice farmers' awareness of environmental protection and their willingness to pay for participating in rice field ecological protection. The variable of high-quality green agricultural products has a significant positive impact on rice farmers' willingness to pay at the level of 5%. High-quality green agricultural products can meet rice

farmers' demand for healthy food, so their willingness to pay will be stronger. The variable coefficient of the willingness to adopt lowcarbon technology is not significant.

6. Conclusions

The payment level of rice farmers on protecting the ecological environment of paddy fields is 179.30 yuan / (muy·ear), which can be used as the reference data for formulating the ecological compensation standard of paddy fields in Guangxi. In terms of rice farmers' willingness to pay, rice field area has a significant negative impact on rice farmers' willingness to pay. The proportion of agricultural income, ecological compensation mode, environmental concern and high-quality green agricultural products have a significant positive impact on rice farmers' willingness to pay.

7. Discussion

This study may have the following shortcomings: (1) The final rice field ecological compensation standard according to the conditional value method in this study is 179.30 yuan/(mu·year), and there is no relevant policy on rice ecological compensation in the study area, and there is no current compensation standard data and the research results for comparison and analysis. Therefore, after the relevant government agencies issue relevant policies in the future, they can conduct follow-up research on rice farmers and consumers participating in this survey, in order to effectively revise the research results. Although this survey was supported by the Guangxi Academy of Agricultural Sciences and local municipal agricultural technology extension stations, it could only be carried out online due to objective conditions. In the future, this survey of respondents can be followed up to obtain more information.

The compensation method was not explored. According to the ecological environment, "who protects, who benefits; Who pollutes, pays", the subject of ecological compensation includes not only the beneficiaries of the positive externalities of the ecological environment, but also the producers of the negative externalities of the ecological environment. Ecological compensation aims to adjust the interest relationship between ecological benefit providers and beneficiaries, ecological environmental protection and destroyers. Theoretically, the main body of agro-ecological compensation is the beneficiary of agro-ecological benefits, but ecological benefits belong to public goods, with noncompetitive and non-exclusive characteristics of consumption, and all the public are beneficiaries of agro-ecological benefits. Therefore, the government, as the representative of the people, has become the main body of agro-ecological compensation. Farmers improve the agro-ecological environment by adopting low-carbon agricultural production technologies such as soil testing formula fertilization and biopesticide application, providing agricultural ecological benefits. However, the production cost of farmers increases, their personal marginal benefits are less than the marginal benefits of society, and their low-carbon production behaviors generate external economy, so farmers should be the subject of compensation for agricultural ecological compensation.

Financial compensation is one of the most direct ways of agro-ecological compensation, which can directly realize the value transfer of ecological benefits and economic benefits between the compensated subject and the compensating entity, and quickly adjust the conflict of interests between the agro-ecological benefit provider and the beneficiary. The fund-raising channel is the key to financial compensation, and the source of funds mainly includes the following three ways: (1) loans or donations from international organizations. In terms of the practice of agroecological compensation through loans from international organizations, Guangdong Province implemented the World Bankfinanced agricultural non-point source pollution control project from 2014 to 2018, aiming to promote environmentally friendly production techniques to reduce water and soil pollution from agricultural production. For example, to incentivize farmers to adopt soil testing formula fertilization techniques, the World Bank project subsidizes 25% of the retail price of soil testing formula fertilizers. (2) Government subsidies. Government subsidies and transfer payments are the most common sources of funds in agroecological compensation, and from the perspective of the beneficiaries of agroecological benefits, the entire public has obtained positive externalities of ecological benefits. As the representative of the people, the government becomes the main body of compensation, and government subsidies and transfer payments are the main ways of compensation. (3) Beneficiary payment. In

agroecological environmental protection, farmers mainly act as providers of ecological benefits, and consumers are the beneficiaries of ecological benefits in paddy fields. Starting from the beneficiaries, consumers enjoy the ecological benefits after the improvement of the agro-ecological environment, and the agricultural ecological compensation funds should be paid by the consumers.

8. Policy implications

Increase awareness of the ecological benefits of rice fields and the importance of ecological environmental protection. The local government's environmental protection department can collaborate with public welfare environmental protection organizations to launch agricultural environmental protection campaigns. This will enhance rice farmers' awareness of their environmental responsibilities and boost their continuous participation in the ecological preservation of rice fields. At the same time, village cadres and other rural elites are encouraged to play a leading role, strengthen ties with rice farmers, and improve their understanding and support of ecological compensation policies.

The degree of ecological compensation support and economic benefits are the core factors affecting the compensation of rice farmers, so the local grassroots government needs to strengthen the publicity of policy knowledge related to ecological protection, improve the awareness level of rice farmers on ecological compensation, and improve the degree of support for ecological compensation. At the same time, the government can collaborate with scientific research institutes and agricultural enterprises to promote low-carbon rice cultivation technology. By conducting low-carbon rice technology training programs, the goals of scientific rice cultivation, improved rice quality, and increased yield can be achieved. This not only enhances the economic benefits of low-carbon rice but also encourages rice farmers to actively participate in the ecological protection of rice fields, thereby improving the ecological environment of these areas.

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