Analysis of Farm Households' Willingness to Participate in Ecological Compensation for "Rice-to-Dryland" Conversion in the Miyun Reservoir Watershed: A Postprint

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Abstract

In recent years, the Beijing Municipal Government has implemented the "Rice to Dryland" ecological compensation project in the upstream area of the Miyun Reservoir to ensure urban water supply security, and the active participation of upstream farmers constitutes the key to project success. Based on household survey data, this study employs a choice experiment model to analyze the characteristics of farmers' willingness to participate in the "Rice to Dryland" project across three townships in Fengning County, Hebei Province, located upstream of the Miyun Reservoir. The study quantitatively estimates the influence of six choice attributes on farmers' participation willingness: "contract duration," "whether mid-term exit is permitted," "proportion of land participating in the project," "reduced fertilizer use," "whether irrigation is permitted," and "subsidy amount." With the exception of "proportion of land participating in the project," all remaining attributes exert significant effects on farmers' project participation willingness. On this basis, the marginal effects and marginal willingness to accept (WTA) for each significantly influential choice attribute are estimated. The results indicate: (1) Farmers exhibit preferences for the choice attributes of "mid-term exit permitted" and "short contract duration," reflecting sustainability risks inherent in the project. These risks can be addressed by creating additional non-agricultural employment opportunities suited to local labor characteristics; (2) "Irrigation not permitted" and "reduced fertilizer use" have emerged as two factors hindering farmer participation. At the current stage, technical training may be employed to improve farmers' environmental awareness, thereby mitigating the adverse impacts of farmers' production behavior on project effectiveness; (3) The compensation amount demonstrates limited effectiveness in mobilizing farmer participation, whereas several other choice

attributes exhibit superior characteristics for mobilizing farmer participation. Therefore, efforts may be made to enhance farmers' autonomous participation decision-making and introduce flexible contract mechanisms to effectively attract farmer participation while conserving compensation funds; (4) Different townships exhibit differentiated willingness to participate in the "Rice to Dryland" project. Compared with agricultural townships, non-agricultural industry townships maintain relatively higher compensation expectations. Consequently, future efforts should consider abandoning the previous one-size-fits-all approach across regions and design diversified compensation strategies.

Full Text

Preamble

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Analysis of Rural Households' Willingness to Participate in the "Paddy-to-Dry" Ecological Compensation Program in the Miyun Reservoir Watershed

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Abstract: In recent years, the Beijing Municipal Government has implemented the Paddy Land-to-Dry Land (PLDL) program in the Miyun Reservoir catchment to ensure the security of Beijing' s water supply, and the participation of rural households is key to the program' s success. Based on survey data from rural households in three townships of Fengning County, Hebei Province, upstream of the Miyun Reservoir, this study used choice experiment modeling to quantitatively estimate the effects of six choice attributes—contract length, contract release option, proportion of total land area enrolled, mandatory fertilizer use reduction, allowance of irrigation, and subsidy level—on rural households' willingness to participate in the PLDL program. Except for the proportion of total land area enrolled, all choice attributes significantly affected rural households' willingness to participate. Based on these initial results, the marginal effect and households' marginal willingness to accept (MWTA) for each significant choice attribute were estimated. The results indicated that: (1) Rural households preferred the option to be released from their contracts and shorter

contract lengths, thereby identifying a sustainability risk for the program, which could be addressed by creating more off-farm employment opportunities in accordance with the characteristics of local labor forces. (2) The restriction of irrigation and mandatory fertilizer use reduction both inhibited program participation, and in the current phase, these issues should be addressed by improving rural households' environmental awareness through relevant technical training to improve their production activities. (3) Meanwhile, subsidy level limited the motivation of rural household participation, whereas the other choice attributes were more effective, suggesting that allowing for greater household autonomy in program participation and alternative contractual arrangements should be piloted. (4) Finally, the willingness to participate in the PLDL program varied across different townships, and the township with non-farm industries had a higher compensation expectation than the agricultural township; therefore, the current one-size-fits-all compensation strategy should be replaced with one that considers regional economic characteristics.

Keywords: Miyun Reservoir catchment; paddy land-to-dry land program; choice experiment; Jing-Ji regional cooperation; willingness to participate

Internationally known as Payment for Ecosystem Services (PES), this is an important policy mechanism that effectively combines economic incentives for individuals with the conservation and restoration of natural capital [1]. Programs aimed at curbing environmental degradation and reducing poverty have developed rapidly in both developing and developed countries [2-3]. Changes in livelihoods resulting from program participation, in turn, produce cascading socioeconomic and environmental effects on the program [4]. In most cases, participants refer to local farmers, and their willingness and choices to participate are key to program success [5]. Foreign scholars have found that program participation willingness is influenced by multiple socioeconomic factors, including subsidy amounts [6-8], flexible contract forms [10-12], as well as farmers' own socioeconomic characteristics, economic income [7], and farmland characteristics [7-8]. Factors affecting participation can be divided into those affecting eligibility and those affecting willingness and ability [6]. Beijing is facing a very severe water resource situation [14-17].

Study Area

The Miyun Reservoir was completed in 1960, located in northeastern Beijing, approximately 100 km from downtown Beijing, with a water surface area of 188 km². It is Beijing' s only surface drinking water source, supplying 43.75% of Beijing' s annual water consumption and bearing extremely important strategic responsibilities. The reservoir' s water sources mainly come from the Chao River and Bai River upstream. The entire watershed has a total area of 15,788 km², spanning Beijing and Hebei Province, with 8,765 km² (55.5%) of the watershed area located in upstream Fengning County, Luanping County, and Chicheng County in Hebei Province [15]. Fengning County is located in northern Hebei Province, with a total county area of 8,765 km² and forest coverage of 42.63%.

Both the Chao River and Bai River, the main water sources for Miyun Reservoir, flow through Fengning County, making it crucial for drinking water source protection in the Miyun Reservoir. The county has been designated as an important ecological conservation area upstream of Miyun Reservoir [18]. Under the Jing-Ji regional cooperation policy framework, Fengning County began implementing regional ecological compensation programs, including the "Jing-Ji Ecological Water Source Forest" program covering 2,400 hm^2 and the PLDL program covering 8,133 hm^2 [22]. Based on preliminary research, this study identified Tanghe Township in the Bai River sub-watershed, and Heishanzui Town and Humaying Township in the Chao River sub-watershed as survey townships. Heishanzui Town is a traditional agricultural township, while Humaying Township has emerging mining industries. Both in terms of spatial distribution and industrial structure, these three townships demonstrate strong representativeness.

Methods

As environmental conditions become increasingly severe, environmental goods such as forests have become increasingly scarce. Researching how to effectively carry out conservation and restoration is a primary goal for government environmental policy formulation. Due to the external characteristics of environmental goods, a complete market cannot be established to account for their market value, which creates great difficulties for environmental policy formulation. Western scholars have developed a series of calculation methods for non-market environmental goods value, including revealed preference methods (RP) such as travel cost method, and stated preference methods (SP) such as contingent valuation method (CVM). Choice experiment (CE) is a type of stated preference method that places respondents in a virtual decision-making environment to compare and make choices among several options. Each option consists of attributes with different levels or values, which must include a price option to reveal the factors influencing people' s choices. Compared with revealed preference methods and other stated preference methods, CE has multiple advantages including the observability of preference behavior and the ability to estimate individual attribute values of environmental goods [23-24]. CE has been widely applied in ecosystem service valuation [25], forest management planning [24], biodiversity conservation [26], and natural disaster assessment [23]. In recent years, CE has also been applied by Chinese and foreign scholars to evaluate policy issues such as farmer participation willingness and program sustainability in China' s Sloping Land Conversion Program [27-29] and collective forest tenure reform [30-31].

Model Specification

Based on Lancaster' s consumer theory and random utility theory, in a choice set C, option j with higher utility is selected by individual i. The probability Pij = Pr(Uij > Uia) = Pr(Vij + ij > Via + ia), where Vij and Via represent

the systematic, observable utility of different options, and ij and ia represent random errors. Here we assume follows a Gumbel distribution, and the difference in random error terms between options also follows a Gumbel distribution. When the Independence from Irrelevant Alternatives (IIA) assumption is satisfied for all options, the choice probability can be expressed using conditional Logit or multinomial Logit (MNL): Pij = e^(Vij) / Σ e^(Via) = e^(Xij) / Σ e^(Xia), where Xij is the vector of choice attributes, is the vector to be estimated, and is the scale parameter [23-24]. Maximum likelihood estimation is used to estimate , with the likelihood function constructed as follows: when individual i selects option j, dij = 1; otherwise dij = 0.

The estimation of Uij can be transformed into the following empirical model: Uij = 1Attr1ij + 2Attr2ij + ···+ nAttrnij + ij. The marginal effect (ME) can be derived from this. Marginal willingness to accept (MWTA) is also called implicit price, which is a point estimate of the value of a unit change in a non-price choice attribute [26]. MWTA actually represents the marginal rate of substitution (MRS) between the price attribute and other attributes. Based on this, the total willingness to accept (TWTA) at different utility levels can be estimated—the total compensation required to move from the current utility level V0 to the post-choice utility level V1.

Questionnaire Design

The Multinomial Logit (MNL) model was used. Based on preliminary research and data collection, this study initially determined the choice attribute set as shown in Table 1.

Summary of the attribute space in the CE design of the Paddy Land-to-Dry Land (PLDL) program

The above choice attributes were determined based on program objectives and farmers' economic interests, reflecting the program' s water conservation and water quality protection goals, revealing program sustainability, measuring program effectiveness, and reflecting farmers' economic considerations. According to the attribute value ranges, this study could obtain 360 option combinations (3×2×3×4×2×5 = 360). Orthogonal design was further used to streamline options to achieve the goal of fitting respondents' basic preference functions [23]. Each choice set in this study used three options (A, B, C) plus a non-participation option to isolate the effect of individual attributes on choices [24].

Data Collection

Field surveys were conducted in Fengning County in November 2015. With the assistance of local forestry bureau staff and village officials, representative sample villages and households were randomly selected. Surveyors conducted choice experiment surveys through structured interviews in farmers' homes and collected socioeconomic information through year-end 2014. A total of 315

households were interviewed, with 300 valid samples (95.2% validity rate). The specific composition is shown in Table 3.

Counts and composition of sampled townships, villages and households

Results

Description of Household Socioeconomic Conditions

Table 4 shows the land and labor input status in the study area.

Summary of land and labor inputs for sampled townships

The differences among the three townships in terms of natural endowments and livelihood activities are clear. In terms of per capita farmland and forestland area, Tanghe Township has abundant land resources. The upstream area of Miyun Reservoir generally lacks water, and under the environment where surface water irrigation is restricted, the number of wells owned per household in Tanghe Township is far lower than the other two townships, indicating lagging infrastructure conditions. From the perspective of labor input, Tanghe Township invests the most labor in agricultural and forestry production, which is consistent with land characteristics. Due to lagging local irrigation conditions, agricultural and forestry production efficiency is low, forcing Tanghe residents to invest more labor in other livelihood activities. Humaying Township, with more non-farm employment opportunities, has the highest number of off-farm work days, leading to lower local dependence on agricultural and forestry production compared to the other two townships.

Figure 1 further verifies these findings by showing the income structure of the three townships.

[Figure 1: see original paper] Comparison of income structure between sampled townships

Humaying Township' s per capita household fixed assets and savings are significantly higher than the other two townships, not only consistent with the above analysis but also further implying that Tanghe Township has a higher overall dependence on primary industry, while Humaying Township has more non-farm employment opportunities and higher overall livelihood levels.

MNL Model Estimation Results

The MNL model was used to estimate how each choice attribute affects farmers' program participation willingness. The specific results are shown in Table 5. All estimation results passed chi-square tests, indicating good model fit.

MNL estimation results of choices of participation in the PLDL program

All attributes except proportion of land enrolled showed significant correlations. The estimated coefficient for contract release option (0.737) is much larger than

other attributes, indicating that allowing exit can greatly stimulate farmers' participation willingness. The survey found that most young and strong laborers work outside, with elderly and women staying at home year-round. Due to institutional and market constraints, they lack sufficient off-farm employment opportunities and income sources, and can only over-invest in and depend on agriculture [32]. Once participating in the program, they worry about participation risks and opportunity cost losses [12]. Like the Sloping Land Conversion Program, this program also faces certain sustainability risks [5,33]. The Alternative Specific Constant (ASC) reflects the utility of households choosing to participate under current conditions [28]. The negative ASC estimate indicates that current conditions alone cannot attract farmers to participate voluntarily, requiring additional policy intervention and implying program sustainability risks. Contract length is significantly negatively correlated with program participation willingness—the shorter the contract, the more it can stimulate participation. The irrigation allowance attribute shows that "no watering" inhibits participation. The fertilizer reduction attribute indicates that mandatory fertilizer use reduction will inhibit participation willingness, reflecting potential threats to the program' s water quantity and quality goals, consistent with findings by Fan Jie [20] and Zheng et al. [16].

Marginal Effects and Marginal Willingness to Accept Analysis

Due to the nonlinear characteristics of the MNL model, the estimated coefficients cannot precisely measure how small changes in attributes affect participation probability. This study estimated the marginal effects (ME) of each attribute and calculated the MWTA based on these. The results are shown in Table 6.

ME and MWTA estimation results of choice attributes for the PLDL program

The marginal effect estimates well reflect the relative magnitude of how unit changes in different choice attributes affect farmers' program participation willingness. The results show that increasing the subsidy to 7,500 yuan/hm² only increases program participation probability by 0.12, while allowing exit and irrigation increase participation probability by 0.127 and 0.057 respectively—higher than the contribution of increasing cash subsidies. The MWTA estimates are consistent with the above analysis and also show clear regional differences. Without corresponding policy measures, the minimum average compensation required for farmers to participate in the program is 6,124 yuan/hm², higher than the current program compensation standard of 4,500 yuan/hm², indicating certain operability for future policy implementation. Comparing different townships, Humaying Township with more non-farm employment (8,390 yuan/hm²) shows higher compensation expectations than the agricultural townships of Tanghe (6,818 yuan/hm²) and Heishanzui (5,381 yuan/hm²). This may be due to the township' s non-farm employment drivers, relatively high economic development level, and farmer income. The negative MWTA values indicate the marginal compensation surplus that farmers can forgo for attribute

level improvements. This further suggests that through designing reasonable policy measures, the dual goals of stimulating program participation willingness and saving investment can be achieved. If improvement measures related to the two attributes (strengthening villagers'autonomous choice and conducting water-saving technical training) are adopted, project investment can be saved by 2,941 and 1,324 yuan/hm² respectively. According to the formula given earlier, the total willingness to accept under the optimal policy combination (allowing exit, no watering, 5% fertilizer reduction) is only 5,381 yuan/hm², effectively achieving efficient fund utilization.

Program Participation Probability Simulation

The fitted probability density function can also simulate how different choice attributes affect farmers' participation willingness as subsidy amounts change. This study simulated two discrete choice attributes (irrigation allowance and contract release option) and their combined effect on participation probability, comparing them with the "no policy measure" scenario (ASC). If both are adopted simultaneously, the subsidy drops significantly to 4,500 yuan/hm². Under the scenario without measures, a subsidy of 7,500 yuan/hm² is needed to achieve the same participation probability. Under the incentive of watering and exit measures, the subsidy drops sharply to 3,000 yuan/hm². The various policy measures not only effectively mobilize farmers' participation enthusiasm but also save compensation funds.

Considering the other two continuous choice attributes (fertilizer reduction and contract length), this study combined them with the previous attributes to form policy scenarios and simulated participation probabilities to understand their impacts.

[Figure 2: see original paper] Simulation of enrollment probability for the different choice attributes

[Figure 3: see original paper] Simulation of enrollment probability for the two policy scenarios

Policy Scenario 1: 5% fertilizer reduction, exit allowed, no watering. Policy Scenario 2: 20% fertilizer reduction, exit allowed, no watering. The results show that Policy Scenario 1 outperforms Policy Scenario 2. Under fixed other conditions, to achieve 0.5 participation probability, Policy Scenario 1 requires cash subsidies of about 4,500 yuan/hm², while Policy Scenario 2 requires about 7,500 yuan/hm². This shows that through optimized combination of different policy measures, program benefits can be maximized.

Conclusions and Recommendations

The Miyun Reservoir watershed ecological compensation program is of great significance for ensuring Beijing's urban water supply security. Based on household survey data and choice experiment modeling analysis of local farmers' program

participation willingness characteristics, this study forms the following conclusions:

First, farmers show certain willingness to participate in the program but strongly prefer the "exit allowed" option, reflecting sustainability risks embedded in the program. Currently, the remaining labor force in the area consists mainly of elderly and women who lack sufficient off-farm employment and income channels and face problems of over-investment and dependence on agriculture. Creating more off-farm employment opportunities suited to local labor characteristics will effectively mobilize farmers' participation enthusiasm and ensure long-term program sustainability. Under-forest economy and eco-tourism demonstration and promotion have shown initial success in the Beijing area [14]. The Beijing and Hebei governments can cooperate to develop these industries, absorb surplus agricultural labor, and create complete industrial chains and off-farm employment opportunities.

Second, irrigation restrictions and mandatory fertilizer reduction have become two factors hindering farmer participation. In the current phase, these can be gradually addressed through technical training to improve farmers' environmental awareness, starting with scientific fertilization, dryland farming, and water-saving irrigation training before gradually regulating their production behavior to reduce possible negative impacts on program effectiveness.

Third, program participation willingness is determined by multiple factors including compensation amount, but while subsidy level has limited effect on mobilizing participation, other choice attributes show good mobilization characteristics. Future program implementation should try introducing flexible contract mechanisms, enhancing farmers' autonomous decision-making. Based on greater initial awareness and participation rights, different standards for contract attributes such as contract duration, subsidy levels, and technical training can be combined into several contract schemes for full discussion with farmers, allowing them to make different choices to more effectively attract participation and achieve efficient use of compensation funds.

Finally, different townships show differentiated participation willingness in the program. Non-farm employment townships have relatively high compensation expectations, while agricultural townships show the opposite, determined by their own location and socioeconomic characteristics. Future implementation should change the previous one-size-fits-all compensation strategy and design diversified compensation strategies. For townships with more local off-farm employment opportunities, non-farm employment technical training and strengthened publicity and guidance can gradually dispel their participation concerns without affecting their off-farm income [34], achieving program benefit maximization.

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Note: Figure translations are in progress. See original paper for figures.