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Sustainable seasonal land fallowing policy to combat groundwater overdraft in China: Insights from a choice experiment

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A R T I C L E I N F O

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A B S T R A C T

The Seasonal Land Fallowing Policy (SLFP) is conducted in the North China Plain to address severe groundwater overdrafts. Optimal compensation standards, fallow duration, and reallocating the saved labor to other employment may enhance SLFP's economic sustainability, while planting green manure crops on fallow land promotes its ecological sustainability. However, unclear farmers' preferences for these policy attributes and supporting measures hinder policymakers from implementing more sustainable SLFP schemes. Based on a choice experiment survey with 716 farmers in Hebei province, our estimation indicates that farmers prefer an SLFP scheme with higher compensation, longer fallow durations, and employment support, but are reluctant to plant green manure crops. Based on the results, the compensation level can be reduced from 500 yuan/mu/year to 460 yuan/mu/year if the current SLFP scheme continues to be implemented. More economically and ecologically sustainable SLFP schemes can be achieved with longer fallow durations and the provision of employment support. Additionally, this study explicitly explores the heterogeneity of preferences for the SLFP scheme between small-scale and large-scale farmers in China and proposes differentiated SLFP schemes for each group.

1. Introduction

Groundwater overdraft is a significant resource and environmental challenge many regions face globally [1–4]. In response, many countries have implemented water management measures (such as water pricing policies, water rights, and extension of water-saving technologies) to reduce the demand for irrigation water [5,6]. However, some studies have indicated that these measures might not result in real water savings, highlighting that increasing irrigation efficiency does not necessarily translate to reduced water consumption [7–9]. More recently, policy designers have implemented strategies in the agriculture sector to pursue sustainable groundwater use [10,11]. One example is the Seasonal Land Fallowing Policy (SLFP) conducted in the North China Plain, which faces

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the most severe challenge of groundwater depletion worldwide. SLFP provides annual monetary compensation to motivate participants to fallow winter wheat in the wheat-maize double cropping pattern. SLFP in China adds one more to the policy package of payments for ecosystem services (PES), which have been employed effectively on a broad scale for controlling soil erosion or preserving the quality of arable land globally [12–17].

Although the SLFP has been implemented over the past 10 years and has reduced groundwater use [18,19], its economic and ecological sustainability remains a pressing issue for several reasons. First, as a government-funded PES program, the SLFP implementation area and duration are constrained by the government's total budget and compensation rates. Once government compensation ceases, farmers are unlikely to continue fallowing their land spontaneously. Second, farmers' willingness to participate in the program is influenced by changes in many external factors. For example, wheat prices have risen in China recently, increasing the net revenue from planting winter wheat and potentially reducing farmers' enthusiasm to fallow [20]. Additionally, the SLFP leaves land fallow in the winter without plant cover, exacerbating soil erosion by strong winds in the North China Plain, thus leading to ecological unsustainability [19]. Scholars and policymakers are concerned about enhancing the SLFP's economic and ecological sustainability under limited budget constraints.

The economic sustainability of the SLFP can be enhanced through several strategies. The first and foremost one is to identify a more reasonable compensation standard. Payments for groundwater conservation need to be sufficient to compensate farmers for land opportunity costs. Some studies have assessed the rationality of the current compensation level in the SLFP by comparing it with the opportunity cost of participating in the program, thereby forgoing the net revenue of wheat [21–23]. However, measuring opportunity cost is challenging, and the calculated opportunity cost is sensitive to price, discount rate, etc. [24–26]. Zuo et al. [27] estimate farmers' willingness to accept compensation for SLFP using contingent valuation methods. The limitation of this method is that it only identifies farmers' preferences for compensation. Achieving sustainability cannot rely solely on lowering the compensation standard, as excessively low compensation may undermine farmers' willingness to participate in fallow programs. Farmers' participation decisions can also be influenced by other policy attributes or supporting measures related to the program. Consequently, the willingness to accept compensation may be reduced if other program attributes are altered or additional support measures are introduced. However, few studies have shed light on how these non-monetary attributes and supporting measures can help formulate a lower compensation level in SLFP.

One of these non-monetary attributes is fallow duration, the contract length that farmers engage in the program [28]. The current SLFP scheme reassesses participant eligibility annually, making its duration only one year. One may wonder if extending the contract length can increase farmers' participation. However, this question cannot be answered clearly in the literature. In some PES literature, shortening the contract length could boost participation [24,29,30]. The major finding in the literature is that farmers pursue flexibility to change land use due to the potential uncertainty about the program effects and market conditions. Other studies find that farmers prefer a longer duration, such as Yu et al. [31]. Therefore, it is essential to examine whether farmers prefer fallowing the land for longer than one year.

The long-term success of a PES program depends on whether its participants can find alternative livelihoods to growing crops [32,33]. Fallowing land saves the labor force of farmers' households, allowing them to take up non-farm occupations and earn additional income. There is substantial evidence showing that participating in the Grain-for-Green program in China reduces households' agricultural production activities [34], shifts their labor endowment from on-farm work to the off-farm labor market [35,36], and facilitates out-migration [37,38]. Consequently, if more farmers can engage in other employment after participating in the SLFP program, they will continue fallowing their farmland in the future with a lower compensation level, or even without any compensation. Chinese farmers have commonly engaged in non-farm activities for additional income since the average farm size is too small to sustain a household's livelihood [39–41]. However, transferring agricultural labor in China is hindered by a lack of job information and training for some farmers. Hence, employment support may help to break these barriers and enable farmers to engage in the non-farming sector. It is unclear how providing employment support affects farmers' participation and how much compensation can be substituted.

In addition to economic sustainability, the program should consider ecological sustainability to align with the goal of green development in agriculture. Implementing SLFP puts the land at risk of soil erosion and fertility degradation. One effective conservation measure is planting green manure crops during the fallowing season, which mitigates SLFP's adverse impacts on the land ecosystem and provides benefits such as improved soil fertility, increased crop yield, and reduced risk of nitrogen loss [42,43]. Although green manure crops can provide important ecosystem services, some studies show farmers are reluctant to adopt them without sufficient incentives provided by the government [44,45]. Nevertheless, given that green manure crops offer considerable positive externalities, how to integrate them into SLFP while adhering to budget constraints is worth investigating.

Furthermore, the past 40 years have seen an increase in the number of large-scale farmers, characterized by much larger land holdings (officially defined as larger than 33.3 ha) compared to traditional small-scale farmers (on average, only 0.7 ha in 1985) in Chinese agriculture [46,47]. With this increase, large-scale farmers have become significant participants in the SLFP, accounting for approximately 40 % of the SLFP implementation areas [48]. Extensive literature provides evidence of varying land productivity caused by farm size [49–51]. Therefore, there is a significant likelihood of heterogeneity in the preferences between small-scale and large-scale farmers. Some studies have found that the scale of farmlands significantly affects farmers' participation in fallowing programs [21,52,53]. However, these studies focus on variations in farm size within the range of small-scale farms, as they include only small-scale farmers in their samples. Exploring this heterogeneity in designing land fallowing policies and creating differentiated schemes may make the SLFP more efficient and sustainable. However, to our knowledge, no research has shed light on it.

Choice experiment is a valid method to explore these issues, which allows for stated preferences in a hypothesis condition [54,55]. A plethora of studies conduct the choice experiment design for land preservation and conservation practices [56,57] as well as for other water-related payments for ecosystem services (PES) practices [58–61]. Three research questions regarding the SLFP are explored using the choice experiment approach: First, what are farmers' preferences for compensation level, fallow duration, employment support, and green manure fallow? Second, how can we identify the rational compensation level if the current SLFP scheme continues? Furthermore, how can we optimize the SLFP scheme to achieve economic and ecological sustainability without compromising farmers' participation? Finally, do preferences for these program attributes and supporting measures vary between small- and large-scale farmers, and how would differentiate SLFP schemes affect policy costs and farmers' likelihood to fallow?

The study contributes to the literature and policy debates in three aspects: First, it verifies how important policy attributes including compensation and fallow duration affect farmers' participation. Figuring out the unclear impact of fallow duration is especially important since it may provide non-monetary solutions for changes in farmers' willingness to participate. Second, this study explores farmers' preferences for supported measures involving employment support and green manure fallow and packages them into the SLFP scheme. Supporting measures may provide new paths to approach SLFP sustainability. However, they are less considered in PES program designs than other policy attributes such as compensation level and fallowing duration. Besides, this study highlights the preferences for fallow policies between small-scale and large-scale farmers. The results are useful for designing concurrent PES programs in the future aiming at both livelihood improvement and environmental conservation in China and other developing countries facing similar challenges.

Although this study primarily focuses on the North China Plain, it offers valuable insights that can be applied to other regions grappling with similar challenges, particularly those facing groundwater depletion due to intensive agricultural practices. The SLFP, as a payment for ecosystem services (PES) model, holds potential not only for China but also for arid and semi-arid regions worldwide, such as parts of India, the United States of America, the Middle East, and North Africa, which are experiencing similar water scarcity issues [62–65]. The findings regarding farmer preferences for compensation levels, fallow duration, and employment support provide critical guidance for designing policies that balance environmental sustainability with farmer livelihood improvements. This research is innovative in its methodological approach, using a choice experiment to capture farmers' preferences and identify key policy attributes that influence their willingness to participate in land fallowing schemes. By highlighting how these preferences can inform the design of more effective and economically sustainable water conservation policies, this study contributes to the broader debate on sustainable agriculture and resource management globally. While the specifics of land use and socio-economic conditions may vary, the core principles of incentivizing sustainable practices and compensating farmers for their opportunity costs can be adapted to various international contexts. Therefore, this study not only contributes to the understanding of SLFP in China but also provides a transferable model that can inform similar water management and agricultural policies in other regions facing groundwater depletion.

The remainder of the paper is structured as follows. Section 2 presents the sampling method and data description, illustrates the choice experiment design, and introduces the estimation method. Section 3 first reports the main estimation results and robustness checks. Then, it presents our simulations to evaluate the current scheme and formulate more sustainable alternatives. Section 4 presents conclusions and policy implications.

2. Methods

2.1. Sample method

We conducted a choice experiments survey, sampling both small-scale and large-scale farmers in 2019. The research site for our survey was strategically set at the four prefectures (Xingtai, Cangzhou, Hengshui, and Handan prefectures) of Hebei province. These areas, chosen due to significant groundwater overdraft in the North China Plain (Fig. 1), account for nearly 90 % of current SLFP implementation zones. We utilized a stratified random sampling method to select farmers based on their participation experience in these four prefectures. We first classified SLFP counties into two types: dominated by small-scale or large-scale participants.[1] Then, we selected small-scale farmers in 7 counties dominated by small-scale participants, and large-scale farmers in 5 counties dominated by large-scale participants. To sample small-scale farmers, we randomly chose two SLFP townships in each sampled county. Within each selected township, one SLFP village and one non-SLFP village were identified. Subsequently, 20 small-scale farmers were randomly chosen from each sampled village. The sampling process yielded 558 small-scale household farms, with 247 participating in SLFP by 2019. Large-scale farms may span multiple villages, and the number of large-scale farmers is minimal in each, making it difficult to sample villages and townships for these farmers. Instead, Large-scale farmer respondents were randomly selected from both participant and non-participant groups in each county, using a list provided by the county government. Ultimately, we surveyed 158 large-scale farmers, including 106 who participated in SLFP by 2019.

During the survey, face-to-face interviews were carried out with representatives of small-scale farms and managers of large-scale farms. The same choice experiment was conducted for both groups of respondents. In total, the 716 (588 + 158) respondents participated in 6 choice experiments, each comprising 3 alternatives. This yielded a total of 12,888 (716*6*3) observations. In addition to the choice experiment survey, we collected comprehensive data on farmers' socio-economic characteristics and their farms' irrigation conditions. Based on these data, we established eight variables to capture the characteristics of farmers, including socio-demographic aspects such as age, gender, education, non-farming work experience, risk attitude, and assets. The definitions of these variables are provided in Appendix Table A1, while their summary statistics are presented in Appendix Table A2.

[1] This is because, in some SLFP counties, small-scale farmers are the dominant participants (occupying more than 50 % of SLFP areas), while in other SLFP counties, large-scale farmers are the dominant participants.

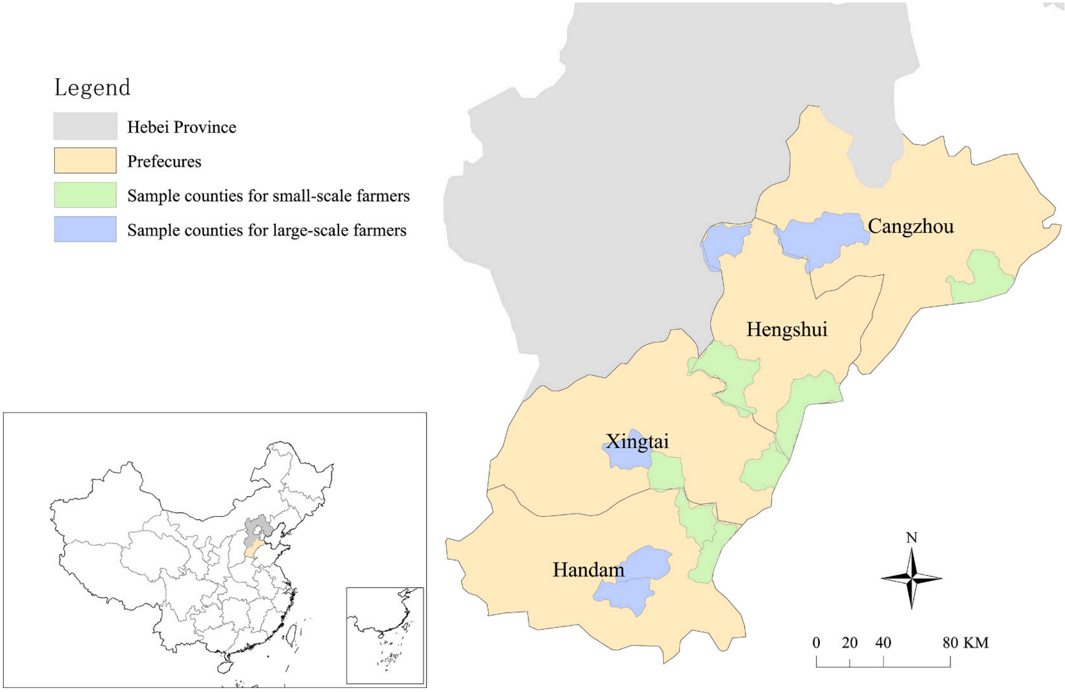

Fig. 1. Location of sample counties.

2.2. *Choice experiment design*

2.2.1. *Set and level of attributes (or supporting measures)*

The choice experiment assumes that an individual's decision to participate in the program (or provide ecological services) depends on the program's attributes and supporting measures. We characterized SLFP packages with two attributes (compensation and fallow duration) and two supporting measures (employment support and green manure fallow). Including monetary attributes is typically imperative in designing choice experiments [66]. Fallow duration is selected because it may have a greater impact on decisions regarding time reallocation and production. Employment support aims to provide job information and free training to farmers, helping to find alternative livelihoods for farmers. Green manure fallow is included to explore how to achieve the ecological sustainability of the SLFP. The set and level for each of the four attributes (or supporting measures) in our design were informed by pretests conducted in Hebei province, consultations with government officials at various levels, farmers' representatives, agricultural experts, and practices observed in the pilot region of the current SLFP scheme (Table 1).

The levels of the two attributes were determined with reference to the design of current SLFP schemes. For compensation, in the pilot phase of the SLFP in Hebei, the annual compensation was set at 500 yuan per mu per year, which approximately matches average opportunity cost of participating in the SLFP- the net revenue farmers forgo from growing winter wheat, as presented in Appendix Figure. B1. We defined the compensation levels as 300 yuan/mu/year for the low end, 500 yuan/mu/year as the median, and 700 yuan/mu/year for the high end, to correspond with low, medium, and high compensation tiers. For the fallow duration, the pilot policy set the fallow duration at one year in most areas. However, during pretests, county officials reported signing annual contracts with the same farmers for three consecutive years, making the actual duration three years. Hence, these two durations are set as the levels of fallow duration. Additionally, we introduced a category for five consecutive years to encompass a longer enrollment period.

Both supporting measures were set as discrete binary choices. Employment support includes job information and free job training, which the government will provide. The government has an advantage in doing this due to its greater ability to access job-related information and facilitate training programs by providing infrastructure. While farmers may have preferences for specific forms of employment support, this study focuses on their general preference for the supporting measures. Hence, we set it as a discrete binary choice: 1 indicates that employment support is provided for farmers, and 0 otherwise. Green manure fallow is also set as a discrete binary choice: 0 represents that farmers are not required to plant green manure crops on the retired land, and 1 represents that they are. However, farmers rarely grow green manure crops spontaneously since it generates extra input costs without yielding farm products, while the potential improvement in soil fertility cannot be observed in the short term [19]. To make it executable, we assume that the additional cost should equal the cost of planting green manure crops and would be covered by the government.

2.2.2. *Experimental design*

The experimental design generates SLFP schemes (i.e., choice sets) through a combination of attributes (or supporting measures) and their levels. Each choice set presents two options offering distinct fallowing schemes, and an opt-out option allowing farmers to opt

Table 1
Set and level of attributes (or supporting measures) in the choice experiment.

Attribute (or supporting measure)	Variables setting and levels
Compensation	Annual compensation provided to participants: (1) 300 yuan/mu/year; (2) 500 yuan/mu/year; (3) 700 yuan/mu/year
Fallow duration	The duration of the program: (1) 1 year; (2) 3 years; (3) 5 years
Employment support	Dummy variables:=0 if job information and free job training are not provided;=1 if job information and free job training are provided
Green manure fallow	Dummy variables:=0 if rainfed green manure crops (e.g., rape) are not required on retired land in winter and spring;=1 if rainfed green manure crops (e.g., rape) are required with additional subsidies on retired land in winter and spring

Note: 1mu = 0.667 ha. Yuan 7.29 = USD 1 in 2019.

out. Since it was impossible to implement the complete choice sets from all the possible 1296 choice sets. We generated a fractional experiment design using the D-optimal design method by the Ngene software (version 1.1.1).

Specially, we first determined that the number of choice sets is 6 by applying the Sato-Tsukahara equation [54].[2] Then, we choose the 6 subsets of the pool of all possible choice sets by optimizing the D-efficiency of the design which can explicitly incorporate prior information on preferences observed from our pretests [68]. The 6 choice sets are listed in Appendix Table B1. Our design is 90.9 % D-efficient compared to the optimal.

The results from the choice experiment are subject to the influence of potential hypothetical bias from stated preferences, which reflects the difference between the hypothetical and actual statements of value. We adopted the following measures to mitigate hypothetical bias in implementing the CE. First, we offered farmers cheap talks, a commonly used *ex ante* approach attempting to persuade and remind the respondent to give more thoughtful answers prior to the valuation question [69,70]. The cheap talks consist of three components (see Appendix B for details): (1) An introduction to the program overview; (2) An explanation of the attributes and supporting measures in simplified language to ensure interviewees understand the attribute meanings; (3) Guidance on answering rules. Second, we provided an illustrative choice set on a sample card and instructed farmers to choose (Table 2). This step ensured that farmers thoroughly understood the choice experiment setup. Farmers were allowed to choose from the six formal choice set cards only after selecting from the sample card and explaining their choice to the interviewer. Third, pictorial visual aids were employed to mitigate interviewer bias and address language-related issues [71]. A choice card with pictorial visual aids is seen in Appendix Table B2.

2.3. Econometric models for estimating farmers' preferences

2.3.1. Model settings

We model farmers' choice of schemes invoking the standard random utility framework, which assumes that choices are based on utility comparisons between the available alternatives and that the alternative providing the highest utility will be the preferred choice. The mixed logit model (random parameter logit model) is chosen as the benchmark model to analyse our data since it allows the utility parameters to vary flexibly across choice makers. This implies that the same choice attributes (or support measures) may induce heterogeneous implications for the utility levels of different choice makers [72]. The random utility function in the random parameter logit model takes the following form:

$$U_{ij} = V_{ij}(c_j, x_j, F) + \varepsilon_{ij} \tag{1}$$

where respondent i receives utility U choosing alternative j from a choice set. The utility U is decomposed into a non-random indirect utility component V and a stochastic term ε; The indirect utility V is assumed to be a function of compensation level c, a set of the non-monetary choice attributes (or supporting measures) x and the features of farmers F. For a rational decisionmaker i, the probability of selecting j from a choice set C is

$$P_{ij} = P[(V_{ij} + \varepsilon_{ij}) > (V_{ik} + \varepsilon_{ik})] \quad \forall j \neq k; j, k \in C \tag{2}$$

We assumed that the indirect utility function V_{ij} is a linear combination of the attributes, supporting measures and features of farmers. In this case, the utility function U_{ij} takes the following form:

$$U_{ij} = \alpha_j ASC_{ij} + \beta_{m,j} c_{ij} + \beta_{n,j} x_{ij} + \gamma_{ij}(ASC_{ij} {}^* F_i) + \varepsilon_{ij} \tag{3}$$

where $j = 0, 1, 2$ for the three scenario options; ASC is the alternative specific constant defined as $ASC = 0$ for the status quo option and 1 for SLFP options 1 and 2. The coefficients α_j, $\beta_{m,j}$, $\beta_{n,j}$ capture the marginal utility of ASC, c, x. The set of coefficients γ_{ij} can be

[2] This equation is in the form S ≥ K/(J-1), where S represents the number of choice sets, K is the number of attributes (4 in this study), and J is the number of options within each choice set (excluding the opt-out option, which is 2 in this study). Consequently, the minimum value for S should be 4. The number of choice sets, 6, was determined to satisfy the minimum value requirement and to avoid cognitive burden or task complexity for respondents [67].

Table 2
Example choice question: Suppose the government was considering the following 3 scheme options for seasonal land fallowing policy, which scheme option would you prefer the most?

Attribute	Option 1	Option 2	Option 3
Compensation	500 (yuan/mu/year)	500 (yuan/mu/year)	Opt-out
Fallow duration	1 year	5 years	
Employment support	not provided	provided	
Green manure fallow	not required	required	
Please choose one:			

Note: 1mu = 0.667 ha. Yuan 7.29 = USD 1 in 2019.

interpreted as the relative propensity of choosing opt-out for the individual i with the features of farmers F_i. Since the compensation usually increases farmers' utility levels, we take the unknown coefficient β_m on compensation variables as fixed, and coefficients β_n on non-monetary attributes variables and ASC as random. The random coefficients on these non-monetary attributes (or supporting measures) and ASC are assumed to be normally distributed. The mixed logit models are estimated in Stata 18 using the simulated maximum likelihood estimation approach with 500 Halton draws.

Table 3
Regression results of the mixed logit model using the full samples.

	Model 1	Model 2	Model 3
	without interactions and no correlations	with interactions and no correlations	with interactions and correlated parameters
Coef.			
Compensation	0.02***	0.02***	0.02***
	(0.001)	(0.001)	(0.001)
Fallow duration	0.14***	0.14***	0.19***
	(0.03)	(0.03)	(0.03)
Employment support	0.75***	0.75***	0.70***
	(0.09)	(0.09)	(0.09)
Green manure fallow	−1.09***	−1.09***	−0.85***
	(0.14)	(0.14)	(0.13)
ASC	−9.25***	−10.31***	−11.25***
	(0.48)	(1.30)	(1.36)
Std.dev.			
Fallow duration	0.33***	0.31***	0.38***
	(0.05)	(0.05)	(0.04)
Employment support	1.12***	1.10***	1.15***
	(0.13)	(0.13)	(0.13)
Green manure fallow	2.50***	2.47***	1.17***
	(0.17)	(0.17)	(0.13)
ASC	3.23***	3.09***	3.54***
	(0.23)	(0.22)	(0.28)
Interactions of ASC with			
Age		0.04**	0.04**
		(0.02)	(0.02)
Gender		−0.66	−0.55
		(0.51)	(0.51)
Education		0.19**	0.14**
		(0.05)	(0.06)
Non-farm experience		0.56*	0.60**
		(0.29)	(0.30)
Risk attitude		−0.04	−0.03
		(0.05)	(0.05)
Asset		0.04	0.12
		(0.27)	(0.28)
Water-saving irrigation		−2.18***	−2.25***
		(0.38)	(0.40)
Well depth		0.22*	0.19
		(0.11)	(0.12)
Observations	12,888	12,888	12,888
Log likelihood	−2989	−2962	−2924.
AIC	5995.	5957	5893
BIC	6062	6084	6065
LR $\chi 2$	1344	1258	1334
McFadden's R^2	0.18	0.18	0.19

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion, Coef. = Coefficient, Std.dev. = Standard deviation.

2.3.2. Post estimations

To intuitively measure and compare farmers' preferences for the non-monetary attributes (or supporting measures), we calculated MWTA (marginal willingness-to-accept) using the estimated parameters from the mixed logit model. The MWTA estimate for a non-monetary attribute β_n is given by the marginal utility ratio between this attribute and the compensation attribute β_m:

$$MWTA_n = -\frac{\beta_n}{\beta_m} \quad (4)$$

MWTA represents the rate at which a farmer would give up one-unit monetary compensation in exchange for a one-unit change in the level of another attribute or the provision of supporting measures while maintaining the same level of utility. The negative sign is to make the negative value of the MWTA to become a positive value.

The WTA under different SLFP schemes can be given by calculating the welfare changes from quantity change of attributes and supporting measures from status quo to alternative SLFP schemes, which is also known as compensating surplus (CS) in the literature [29,73]. The CS should be set as the minimum compensation in the SLFP schemes to make the respondent indifferent between the schemes and the status quo. We can determine the appropriate compensation level for the particular SLFP scheme by calculating the WTA, as shown in equation (5):

$$WTA_{ij} = -CS_{ij} = -\frac{V_{i,j} - V_{i,o}}{\beta_m} = -\left(\frac{\alpha_i + \beta_n x_j + \gamma_{ij} F_{ij}}{\beta_m}\right) \quad (5)$$

where $V_{i,0}$ represents the indirect utility function at the status quo which is set to 0, and $V_{i,j}$ represents the indirect utility in scenario j.

The probability of choice j from all the choices C is the exponentiated utility of the chosen option divided by the sum of all the exponentiated utilities among all the alternatives, with the equation as follows:

$$P_{ij} = \int \frac{e^{V_{ij}(\varphi_j)}}{\sum_{j \in C} e^{V_{ij}(\varphi_j)}} f(\varphi_j) d\varphi_j \quad (6)$$

where $\varphi_j = \alpha_j,\ \beta_{m,j},\ \beta_{n,j}$, $f(\varphi_j)$ are the density for φ_j.

3. Results

3.1. Farmers' preferences for attributes and supporting measures

In Table 3, we start with a specification (Model 1) that includes only attributes (or supporting measures) variables; we then estimate a specification incorporating the ASC interactions with the eight observed variables of farmers' features in Model 2. The coefficients of the random parameters are assumed to be independent in both Model 1 and Model 2. We then specify that the random coefficients are correlated in Model 3. The standard errors in each specification are cluster-robust, allowing for arbitrary correlation between the disturbance terms at the individual level. Based on the coefficient estimates of models, we then report the average marginal effects of the attributes (supporting measures) in Table 4. The MWTA of each attribute (or supporting measure) is then estimated using equation (4) in Fig. 2.

All models passed the LR χ^2 test at the statistical level of 1 %, indicating that the equations were overall significant. The McFadden R^2 are all greater than 0.1, suggesting the explanatory power of the model is adequate. Although the estimates are consistent across these three models regarding significance, the smallest value of the information criteria (AIC and BIC) in Model 3 suggests that it fits the data better. The LR test indicates that Model 3, which accounts for parameter correlation, offers more valuable insights into the estimation process than Model 2. Significant standard deviation estimates support the use of the mixed logit model. As a comparison, we also fit the data using the conditional logit model (multinomial logit model), which assumes homogeneous parameters (see Appendix Table C1). The higher AIC and BIC values from the conditional logit model compared to the mixed logit model indicate that incorporating preference heterogeneity significantly improves model performance. We use the latent class model as an alternative model for accounting for preference heterogeneity for the SLFP schemes. The findings indicate that the largest class of farmers exhibit consistent significance patterns for these attributes (or supporting measures), aligning with the outcomes observed in the estimation of the mixed logit model. This finding supports the robustness of our results from the mixed logit model (Appendix Table C2).

Table 4
Marginal effects from choice experiment.

Attributes (or supporting measures)	Marginal effect (%)
Compensation	0.19***
Fallow duration	1.68***
Employment support	6.23***
Green manured fallow	−7.56***

Note: Mixed logit model with correlated parameters (Model 3 in Table 5); marginal effects are the average of the marginal effects calculated for each observation.

Table 5
Regression results of mixed logit model with correlated random parameters by small-scale and large-scale farmers.

	Model 1	Model 2	Model 3
	Full samples	Small-scale farmers	Large-scale farmers.
Coef.			
Compensation	0.02***	0.02***	0.02***
	(0.001)	(0.001)	(0.002)
Fallow duration	0.20***	0.18***	0.20***
	(0.04)	(0.03)	(0.07)
Employment support	0.65***	0.66***	0.99***
	(0.10)	(0.10)	(0.24)
Green manure fallow	−1.02***	−1.08***	−0.18
	(0.16)	(0.16)	(0.29)
ASC	−11.43***	−10.81***	−10.35***
	(1.38)	(1.61)	(2.91)
Std.dev.			
Fallow duration	0.37***	0.42***	0.19***
	(0.05)	(0.09)	(0.07)
Employment support	1.13***	0.42***	0.89***
	(0.14)	(0.09)	(0.25)
Green manure fallow	1.13**	1.02**	0.14
	(0.49)	(0.47)	(0.23)
ASC	3.52***	3.49***	3.54***
	(0.30)	(0.33)	(0.60)
Interactions of farm size with			
Compensation	0.001		
	(0.001)		
Term	−0.06		
	(0.07)		
Employment	0.24		
	(0.20)		
Green manure fallow	0.75***		
	(0.29)		
Interactions of ASC	Yes	Yes	Yes
Observations	12,888	10,044	2844
Log likelihood	−2913	−2293	−602
AIC	5893	4632	1250
BIC	6065	4798	1387
Wald $\chi 2$	387	316	122
McFadden's R^2	0.18	0.20	0.14

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. The interactions of ASC include interactions with the eight variables of farmers' features described in Table 2. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. Coef. = Coefficient, Std.dev. = standard deviation.

3.1.1. *Preferences for policy attributes*

Farmers prefer schemes with high compensation, as indicated by the positively significant compensation coefficient at the 1 % level in each model presented in Table 3. Specifically, increasing the compensation by 100 yuan per mu raises the probability of an SLFP scheme being chosen by an average of 19 %, assuming all other conditions remain unchanged (Table 4). Our initial assumption of a fixed coefficient for compensation implies no heterogeneity in the effect of compensation on farmers' preferences. To test this assumption, we also modelled the coefficient on the compensation variable as random and lognormally distributed among farmers (so the coefficient takes only positive values). The estimated results for these two approaches are presented in Appendix Table C3 and Table C4. The results show that the standard deviation of the compensation variable is not significant in these models, supporting the appropriateness of assuming a fixed coefficient for compensation. In conclusion, farmers consistently prefer schemes with high compensation.

The positive and statistically significant coefficient for the fallow duration variable suggests that an extended fallow duration amplifies farmers' preference for the SLFP schemes. Expanding the fallow duration by one year increases the probability of an SLFP scheme being chosen by 1.68 %. MWTA calculations based on Model 3 in Table 3 suggest, on average, respondents are willing to accept approximately 8.9 yuan/mu/year less in compensation for each additional one-year of seasonal fallow (Fig. 2). We then add a squared term for fallow duration in the setting of Model 3 to verify if there is a nonlinear effect of fallow duration (See Appendix Table C5). The results show that the effect of fallow duration on the likelihood of participation in the scheme presents a U-shaped curve, and the turning point is at 2-year which is calculated by the coefficients of duration and its squared term. This result indicates that farmers' preference increases when the fallow duration exceeds two years. We can be explained from these two aspects: First, extended program duration may mitigate the need for frequent production adjustments among farmers, thereby facilitating 'trouble-free' off-farming employment. Second, compared to other PES programs involving conservation practices, retiring lands is more convenient and less uncertain since farmers do not need to input additional effort to achieve program goals in the fallow land.

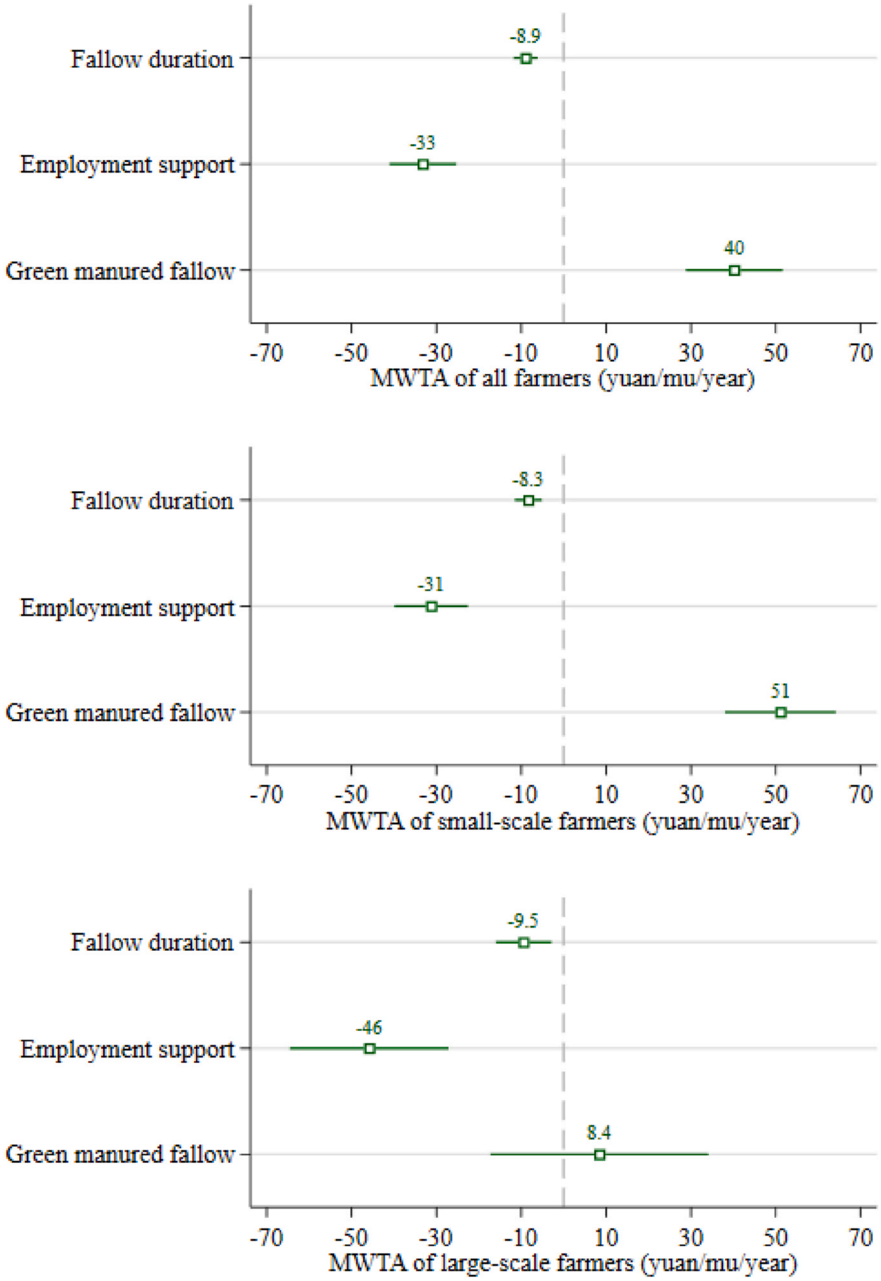

Fig. 2. Marginal willingness-to-accept estimates (MWTA), with 95 % confidence intervals.
Note: The MWTA estimates are labelled for each variable.

3.1.2. Preference for supporting measures

Employment support also positively and significantly affects farmers' willingness to join in the program. Respondents are 6.2 % more likely to choose a scheme if it provides employment support. On average, farmers are willing to accept approximately 33 yuan/mu/year less in compensation in exchange for job information and free job training (Fig. 2). Fallowing in the winter saves part of the labor force of farmers' households, allowing them to take up non-farm occupations to earn additional income. However, some of them lack other employment skills or face barriers to searching job information by themselves. Supporting measures like employment support could ease farmers' job search barriers and help them engage in non-farming employment to acquire non-farming income. Researchers have found that part-time farmers' willingness to fallow would increase as the rise of their non-agricultural income [74].

In contrast, farmers are significantly unwilling to plant green manure crops even if the government would provide the cost to farm these crops in the design of the CE. Respondents are 7.6 % less likely to choose a scheme that requires planting green manure crops on fallow land. Additional compensation of 40 yuan/mu/year may be necessary if rainfed green manure crops are required to farm

(Fig. 2). Farmers' reluctance may stem from a preference to allocate their labor and time to more profitable land conservation practices [24], or from a lack of awareness and understanding of these measures, coupled with limited access to planting skills [75,76]. This finding highlights a trade-off between enhancing the ecological benefits of the fallowing program and minimizing its costs.

3.1.3. How farmers' features affect their preferences

In Table 3, The ASC coefficients are negatively significant, indicating a tendency of farmers to stay status quo (farming their cultivated land) and not to choose options (seasonally retiring their cultivated land with compensation). Farmers' willingness to choose a scheme is also affected by farmers' features. Among the interaction variables of farmers' characteristics with ASC, the positive coefficients of age, education, and non-farm experience indicate that older, higher-educated farmers with experience in non-farm employment are more willing to choose program options. Older farmers are more eager to retire, so they may prefer to join a program option to reduce farmed areas. Farmers with higher education levels and non-farm experience are more likely to participate in the program options since they may be more capable of engaging in non-farming employment after participating in the program [48]. We also find that irrigation conditions of farmlands significantly impact farmers' preferences. Farmers who adopt water-saving field irrigation are unwilling to choose program options. On the other hand, the deeper the wells farmers use, the higher the preference for a program option. The significance of these two variables suggests that farmers with better irrigation conditions are less likely to fallow their farmlands.

3.2. Preferences heterogeneity between small- and large-scale farmers

This section explores the preferences heterogeneity between small-scale and large-scale farmers (Table 5). In Model 1, we first add interactions between the farm size dummy (1 for large-scale farmers, 0 otherwise) and the four attributes (or support measures) to Model 3 of Table 3. We then conduct estimations that exclusively incorporate small-scale and large-scale farmers samples, respectively (Model 2 and Model 3). These models demonstrate overall significance, as evidenced by the χ^2 test results significant at the 1 % level and McFadden R^2 values exceeding 0.1. The mean MWTA with 95 % confidence intervals derived from estimates in Model 2 and Model 3 are displayed in Fig. 2.

The results suggest that small-scale and large-scale farmers have similar preferences for compensation level, fallow duration and employment support (insignificant interaction variables of farm size with these three attributes, Model 1 of Table 5). In Model 2 and Model 3, the coefficients of compensation attribute for small-scale farmers and large-scale farmers are both 0.021, suggesting monetary incentives for them play a similar role in promoting SLFP participation. However, the coefficients' values and corresponding MWTA for duration and employment support vary between the two groups. As shown in Fig. 2, extending the program's duration by one year can make large-scale farmers (9.5 yuan/mu/year) more willing to accept a reduced compensation than small-scale farmers (8.3 yuan/mu/year). Employment support can also make large-scale farmers (46 yuan/mu/year) more willing to accept reduced compensation than small-scale farmers (31 yuan/mu/year). Regardless of the difference, the estimated results indicate that extending the program's duration and providing employment support are efficient approaches to designing more economically sustainable SLFP schemes.

A significant difference in the preference for green manure fallow is found between small-scale and large-scale farmers (significant interaction of farm size and the supporting measures of planting green manure crops, Model 1, Table 5). Small-scale farmers are significantly unlikely to choose a program requiring green mature fallow (Model 2, Table 5). Small-scale farmers need an average additional compensation of 51 yuan per mu per year to plant green manure crops (Fig. 2). In contrast, it does not significantly affect large-scale farmers' preferences (Model 3, Table 5). This difference may be from many aspects. For instance, large-scale farmers may have a better cognition about this land conservation practice than small-scale farmers due to their higher level of education and younger age (see Appendix Table A2). Additionally, large-scale farmers may be more capable of implementing this practice owing to their higher availability or ownership of agricultural machines to substitute labour [77,78]. Furthermore, large-scale farmers, who lease substantial amounts of land, are more likely to engage in this activity since they are stickier in operating agriculture [79].

3.3. Effect of hypothetical bias on estimated results

The application of hypothetical response data in research using the choice experiment approach may not accurately predict actual enrollment responsiveness [80]. Although we provided check talk and an illustrative choice set to relieve hypothetical bias in the design and implementation of the choice experiment, as outlined in Section 2.2, our model's estimated results may still be biased. Conducting a consequential choice experiment, in which respondents believe their survey answers will influence policy and that they care about the outcomes of those policies, is an effective approach to minimise biased responses [81,82]. Following the principle of this approach, we used farmers' participation experience in a pilot SLFP program in the study area to evaluate the potential impact of hypothetical bias and validate the estimated results. Farmers who participated in the pilot program before our choice experiment may better understand the program's design and purpose. Their responses may be more actual, as they may be more confident in the program's implementation than those who did not participate in the pilot program. As a result, the preferences of farmers who participated in the pilot program may better reflect the actual preferences for the SLFP schemes.

As we conducted the survey in the pilot region of SLFP and included the program participants in the sample, about half of the interviewees (49.3 %) participated in the program before and in 2019. To assess the impact of farmers' participation on their preferences, we introduced a dummy variable representing participation experience (1 for program participants, 0 otherwise) into Model 1 of Table 3. The interaction of participation experience with compensation and fallow duration is significantly positive (Model 1 of Table 6). Even when we control for farm size in Model 2 of Table 6, the significance of the interaction with participation experience remains unchanged. These results indicate that participants prefer a scheme with higher compensation and longer contract lengths than the non-participants. We also report the estimated results for non-participants and participants separately by using full samples, small-scale and large-scale farmer samples in Appendix Table C6. In these models, the fallow duration variables are more significant for participants than non-participants. These findings suggest that the estimated preference for compensation and fallow duration may be undervalued due to hypothetical bias reflected by the participation experience in this study. However, farmers' preference for employment support and green manure fallow is not significantly influenced by their participation experience, demonstrating the robustness of the estimated results for these two supporting measures.

3.4. Is the current compensation level reasonable?

3.4.1. Comparison of WTA and opportunity cost

In this section, we compare the current SLFP compensation level with farmers' WTA to evaluate whether the current compensation is reasonable, as WTA estimates under the SLFP scheme serve as a benchmark for reasonable compensation standards by fully accounting for participants' welfare losses [83]. Before this, we compare farmers' WTA for participating in the SLFP with the opportunity cost of participating in the program (net revenue from planting winter wheat). Numerous studies argue that if the compensation level does not sufficiently cover the opportunity cost, farmers may be unwilling to participate in the SLFP program [25,28,86]. Meanwhile, cash compensation (mainly to offset opportunity cost) is a very important attribute determining farmers' preference to choose a SLFP scheme. Therefore, if our estimates are reliable and valid, there should not be a very large gap between WTA estimates and opportunity cost. In theory, WTA compensation should be less than opportunity cost if they are correctly measured, since the acceptable compensation (larger than opportunity cost) can be reduced by the welfare increase from other non-monetary attributes.

Our WTA estimation's reliability and external validity are supported by the close alignment between WTA and opportunity cost. Fig. 3 shows that the mean WTA estimate under the current SLFP scheme from the CE method is 460 yuan/mu/year. For reference, we

Table 6
Regression results of the mixed logit model with correlated parameters considering participation experience.

	Model 1		Model	
	Full samples		Full samples with interaction of farm size	
	Coef.	Std.dev	Coef.	Std.dev
Compensation	0.021***		0.020***	
	(0.001)		(0.001)	
Fallow duration	0.112**	3.520***	0.124***	0.367***
	(0.044)	(0.253)	(0.045)	(0.041)
Employment support	0.593***	0.370***	0.566***	1.151***
	(0.130)	(0.040)	(0.133)	(0.130)
Green manure fallow	−0.860***	1.152***	−0.981***	1.151***
	(0.186)	(0.128)	(0.193)	(0.430)
ASC	−11.225***	1.152***	−11.294***	3.522***
	(1.298)	(0.377)	(1.315)	(0.257)
Interactions of participation experience with				
Compensation	0.001**		0.001*	
	(0.001)		(0.001)	
Fallow duration	0.158***		0.177***	
	(0.056)		(0.057)	
Employment support	0.216		0.181	
	(0.166)		(0.170)	
Green manure fallow	0.022		−0.092	
	(0.244)		(0.248)	
Interactions of farm size with				
Compensation			0.001	
			(0.001)	
Fallow duration			−0.104	
			(0.071)	
Employment support			0.206	
			(0.206)	
Green manure fallow			0.760**	
			(0.302)	
Interactions of ASC with	Yes		Yes	
Observations	12,888		12,888	
Log likelihood	−2911		−2906	
AIC	5875		5860	
BIC	6077		6092	
LR $\chi2$	1310		1311	
McFadden's R-squared	0.17		0.18	

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. AIC=Akaike Information Criterion, BIC=Bayesian Information Criterion, Coef = Coefficient, Std.dev. = Standard deviation.

also estimate WTA using the contingent valuation method (CVM) for the current SLFP scheme. The results support the accuracy and credibility of the WTA estimation, as the mean WTA from CVM is very close to that from CE [85,87,88]. In comparison, the WTA compensation is 14 % lower than the opportunity cost of 525 yuan/mu/year. As expected, the WTA compensation is close but lower compared to the opportunity cost, indicating that farmers' preferences for non-monetary attributes may reduce their acceptable SLFP compensation. Since the WTA compensation is lower than the current compensation level of 500 yuan/mu/year, there is room to reduce the compensation level of current SLFP schemes. This is because, although the current compensation level of 500 yuan/-mu/year is nearly sufficient for farmers to offset their perceived opportunity cost, it can be moderately reduced to the WTA compensation level if the full welfare loss—not just the incentive loss—is considered.

3.4.2. Differences in WTA between small- and large-scale farmers

Large-scale farmers had a higher mean WTA than small-scale farmers under the current SLFP scheme. Fig. 3 shows that the mean WTA of large-scale farmers is 33 yuan/mu/year higher than that of small-scale farmers under the CE method, while the mean WTA of large-scale farmers is 25 yuan/mu/year higher than that of small-scale farmers under the CVM method. This conclusion can be supported by the higher opportunity cost of large-scale farmers (625 yuan/mu/year) than that of small-scale farmers (496 yuan/mu/year), suggesting a higher compensation should be provided to large-scale farmers than small-scale farmers to make up their higher opportunity cost to participate in the program. Yu et al. [89] also find that farmers with larger arable land and higher agricultural output significantly increased their compensation requirements.

3.5. Performance of more sustainable schemes

Based on farmers' preferences, we propose two alternative SLFP schemes for economic and ecological sustainability: (1) Scheme A, which enhances income through employment support and longer fallow periods to reduce costs, and (2) Scheme B, which adds green manure crops to conserve soil fertility while also reducing costs. Both schemes feature 5-year contracts, aligning with farmers' preference for longer durations.[3] We first calculate the WTA given the values of these attributes (supporting measures). Then, the mean WTA estimates are set as the compensation standard for the two schemes (Table 7). We evaluate the performance of the two new schemes against the current SLFP scheme by comparing policy cost and predicted fallow probabilities.

3.5.1. Cost savings compared to current SLFP scheme

Scheme A offers significant cost savings and Scheme B supports greater ecological sustainability with minimal additional cost. Table 8 shows that the mean WTA for implementing Scheme A is 391 yuan/mu/year, 22 % lower than the current SLFP compensation level. For Scheme B, the mean WTA is 431 yuan/mu/year, but with an additional 83 yuan/mu/year for green manure crops, the total compensation rises to 514 yuan/mu/year—a 3 % annual cost increase for enhanced ecological sustainability. The current SLFP scheme encompasses 2 million mu of cultivated land at a total cost of 1 billion yuan in Hebei Province. Applying our estimated compensation and maintaining the current total SLFP areas, we find that implementing Scheme A could decrease the total cost to 0.78 billion yuan annually, whereas implementing Scheme B increases the total cost to 1.03 billion annually over five years (assuming no CPI indexation).

3.5.2. Changes in fallow probability compared to current SLFP scheme

Although the proposed alternative SLFP schemes can save the total cost of implementing the policy, they may reduce farmers' fallow probabilities since the WTA-level compensation is much lower than that in the current SLFP scheme. Using Equation (6), we separately predicted the probabilities for each scheme presented in Table 7. We then compared the probabilities of Schemes A and B to those of the current SLFP scheme. According to our simulation results, the mean predicted probability of participating in the current SLFP scheme is 0.59, indicating an above-average participation probability for the baseline scheme. Implementing Scheme A and B reduces fallow probabilities by 11 and 9 percentage points, respectively (Table 8). However, the probability of farmers choosing either scheme remains close to 50 %, suggesting that both hypothetical schemes can still effectively ensure farmers' participation.

3.5.3. Performance of differentiated SLFP schemes

We propose differentiated SLFP schemes for small-scale and large-scale farmers, varying only in compensation levels while keeping other attributes consistent. Table 8 shows that large-scale farmers require higher compensation (399 yuan/mu/year) than small-scale farmers (385 yuan/mu/year) for Scheme A, likely due to their lower willingness to participate. For Scheme B, small-scale farmers need higher compensation (436 + 83 yuan/mu/year) than large-scale farmers (407 + 83 yuan/mu/year) to offset their reluctance to plant green manure crops. Assuming 60 % of the 2 million mu SLFP area is allocated to small-scale farmers and 40 % to large-scale farmers, differentiated Scheme A maintains the same 22 % cost savings as the uniform scheme. Differentiated Scheme B, however, reduces costs further, increasing total expenses by only 1 % compared to the uniform scheme. Both differentiated schemes show moderate reductions in predicted fallow probabilities (6–13 percentage points). Thus, differentiated Scheme A performs equally well as the uniform scheme, while differentiated Scheme B outperforms its uniform counterpart.

[3] Although our results suggest longer contracts are preferred, we choose the five-year duration because a too-long contract may be unrealistic to execute. Farmers consider a five-year duration feasible, according to our pre-tests in the pilot region.

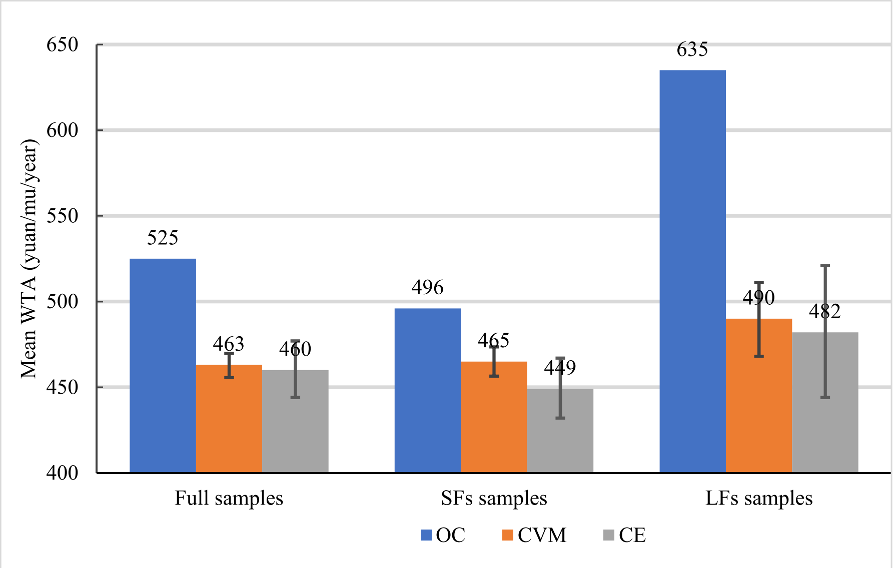

Fig. 3. Mean WTA estimates (yuan/mu/year) for choosing current SLFP scheme under different methods.
Note: OC= Opportunity cost, CVM = Contingent valuation method, CE = Choice experiment, SFs = Small-scale farmers, LFs = Large-scale farmers. The WTA under CE are derived from the estimation of mixed logit model with correlated parameters. The estimation of WTA under CVM is introduced in Appendix D. The lines with the upper and lower bounds represent 95 % confidence intervals which are calculated based on the 'delta' method [84].

Table 7
Attribute changes of representative SLFP schemes.

	Current SLFP scheme	Scheme A	Scheme B
Compensation	500	Mean WTA	Mean WTA
Fallow duration	1	5	5
Employment support	0	1	1
Green manure fallow	0	0	1

Table 8
Simulation results under alternative SLFP schemes.

	Scheme A			Scheme B		
	Full	SFs	LFs	Full	SFs	LFs
Mean WTA (yuan/mu/year)	391	385	399	431	436	407
Unit cost of green-manured crops (yuan/mu/year)	0	0	0	83	83	83
Cost savings comparing to 500 yuan per mu per year (%)	−22	−23	−20	3	4	−2
Total cost of 2 million mu SLFP areas (billion yuan annually over five years, assuming no CPI indexation)	0.78	0.46	0.32	1.03	0.62	0.39
Total cost savings comparing to 1 billion yuan (%)	−22	−22		3	1	
Change in fallow probability (%)	−11	−10	−6	−9	−13	−6

Note: The mean WTAs and probabilities under CE are derived from the estimation of mixed logit model with correlated parameters. SFs = Small-scale farmers, LFs = Large-scale farmers.

4. Conclusions and implications

This study investigates farmers' preference for policy attributes and supporting measures to promote sustainable SLFP piloted in groundwater over-extraction areas of North China Plain. By conducting a choice experiment survey involving 716 farmers, including both small- and large-scale farmers, and estimating the data using the mixed logit model, we find that farmers prefer an SLFP scheme with high compensation. However, the sustainability of the government-paid fallow policy is threatened by limited financial support. It is crucial to improve the design of non-monetary attributes and implement supporting measures to reduce fallow compensation without affecting participation probability. Our CE design and estimation suggest two possible methods: increasing the length of contracts and providing employment support. However, despite additional compensation, farmers are less likely to choose a scheme that plants green manure crops in the fallow season.

The estimated results help to evaluate the rationality and effectiveness of the current pilot policy design. The mean WTA derived from the CE estimation is 460 yuan for the current SLFP scheme, suggesting that the official compensation level (500 yuan/mu/year) is higher than farmers' mean welfare loss. Our simulations also indicate that the sustainability of land-fallowing programs can be improved by setting reasonable compensation levels and design attributes or supporting measures that meet farmers' preferences. Conducting an 'economic sustainability' scheme (involving a 5-year fallow duration and employment support) leads to a 22 % cost reduction compared to the current SLFP scheme. An 'ecological sustainability' scheme that requires green manure fallow with additional costs can be achieved by extending the fallow duration to 5 years and providing employment support with the 514 yuan/mu/year compensation level, resulting in only a 3 % annual increase in cost to implement the SLFP. These alternative schemes can be achieved with a moderate reduction in the participation probability of farmers compared to the current SLFP scheme.

Considering producer heterogeneity allows for the design of more targeted, cost-effective, and sustainable policies that better address different groups' diverse needs and preferences, ultimately enhancing policy effectiveness and participation. Our heterogeneity analysis shows that both small- and large-scale farmers prefer schemes with higher compensation, longer fallow durations, and employment support, but their willingness to accept for these attributes varies significantly. Requiring the planting of green manure crops significantly reduces the preference for small-scale farmers while having no significant effect on the preference for large-scale farmers. Differentiated SLFP scheme simulations indicate that large-scale farmers require higher compensation for the current and 'economic sustainability' schemes due to their higher opportunity and lower participation likelihood, while small-scale farmers need more compensation for the 'ecological sustainability' scheme to offset their reluctance to plant green manure crops.

CRediT authorship contribution statement

Zhuanlin Wang: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hongbo Deng:** Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jinxia Wang:** Writing – review & editing, Supervision, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Alec Zuo:** Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Baozhu Guan:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Jiajia Wang:** Writing – review & editing, Methodology, Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Sample descriptive statistics

Table A1 illustrates the definition of varibles. Among these variables, the non-farm experience variable is binary, taking one if a farmer was involved in a non-farm job before, and 0 otherwise. Risk attitude is measured by asking farmers to rate their risk-taking attitude on a scale from 0 (completely unwilling to take risks) to 10 (very adventurous). Assets are approximated by the number of cars owned by the respondent. Additionally, water-saving irrigation and well depth are included to characterize the irrigation conditions of the farmers' operated farmland. Water-saving irrigation is a dummy variable that equals 1 if water-saving irrigation technologies (including border irrigation, furrow irrigation, pipeline irrigation, sprinkler irrigation, and drip irrigation) are used in farmers' field irrigation and 0 otherwise. The groundwater depth is measured by the average depth of the farmer's main wells.

Table A1
Variables description

Variables	Descriptions
Age	Age of the respondent (years)
Gender	Dummy: equal to 1 if male and 0 if female
Education	Number of school years (years)
Non-farm experience	Dummy:=1 if the respondent engaged in a non-farm job before 2019, 0 otherwise
Risk attitude	Range from 0 to 10, the higher the value, the more risk seeking
Assets	Number of cars owned by the respondent' household
Water-saving irrigation	Dummy:=1 if water-saving irrigation is used in field irrigation, 0 otherwise
Well depth	Average depth of main wells used by respondent (100 m)

Note: 1mu = 0.667 ha. Yuan 7.29 = USD 1 in 2019.

Table A2 presents the summary statistics of the above variables. The average age of sample farmers is 57 years old. The average education level of the respondents is 7 years, equivalent to junior high school. 93 % of the sample was male, indicating men act as primary decision-makers about the farm. 46 % of sample farmers have the experience of non-farm employment. Farmers tend to be risk-averse, as evidenced by their self-reported risk score of 4, which falls below the median. Farmers face severe groundwater overdraft since the average depth of wells farmers use is 175 m in this region. Furthermore, the Student's *t*-test for these variables' mean difference between small-scale and large-scale farmers indicates that large-scale farmers have better human capital and irrigation conditions. For instance, large-scale farmers are 10 years younger than small-scale farmers, averaging 49. Large-scale farmers also have a 2-year higher education compared to small-scale farmers. Large-scale farmers are also more likely to take risks, represented by a higher self-reported risk attitude grade, and possess more assets, represented by having more cars. More large-scale farmers (86 %) use water-saving field irrigation technologies than small-scale farmers (74 %).

Table A2
Summary statistics of variables

Variables	Mean			Mean difference
	full samples	Small-scale farmers	Large-scale farmers	
Age	57	59	49	9.68***
Gender	0.93	0.93	0.92	0
Education	7	7	9	−1.96***
Non-farm experience	0.46	0.45	0.47	−0.02**
Risk attitude	3.54	3.16	4.89	−1.72***
Asset	0.27	0.2	0.54	−0.34***
Water-saving irrigation	0.77	0.74	0.86	−0.12***
Well depth	1.75	1.79	1.61	0.18*

Note: Student's *t*-test is used to compared variables' mean difference between small-scale farmers and large-scale farmers; Asterisks indicate statistical significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Appendix B. Choice experiment design

The Cheap talk.

"Groundwater is an important source of water, but Hebei province has created the largest groundwater funnel area in the world due to overexploitation. If not addressed, agricultural production and drinking water will face severe shortages in the future. Studies show that overexploitation of groundwater is closely related to large-scale winter wheat cultivation. Therefore, the government has been encouraging farmers not to plant winter wheat since 2014 by providing financial compensation, currently 500 yuan per mu. Not planting winter wheat also means farmers have more leisure time. The program will continue for the foreseeable future, with no set end date. However, due to limited funding, the government wants to determine a more appropriate compensation standard to better control groundwater overexploitation in the long run.

Now we would like to know what kind of policy schemes, varying in the level of policy attributes and supporting measures, you prefer. First of all, you must be very concerned about the compensation amount, that is, how much compensation is given per mu per year. Fallow duration means that if you participate in fallow, the number of years that the land needs to be seasonally fallowed. For example, if it is three years, then in each of these three years, one season will be cultivated, and the other season will be fallow in your farmlands. Employment support means whether the government will provide some employment information and free training. Green manure fallow means whether to plant rape or nothing during the fallow period. Of course, there will be some compensation for growing rape, but it cannot be irrigated in any form.

Next, we need you to make a few choices from six choice sets. Each choice set includes two scheme options. Please indicate whether you prefer the first or the second scheme. If you don't like either, you can choose option three, which represents your preference not to participate in the program. Let's take this choice card as an example. In the sample, there are two schemes, each described by different levels of four attributes (or supporting measures). If you choose one of the schemes, it means you find it more attractive than the other schemes. Now, please tell me which one you would choose".

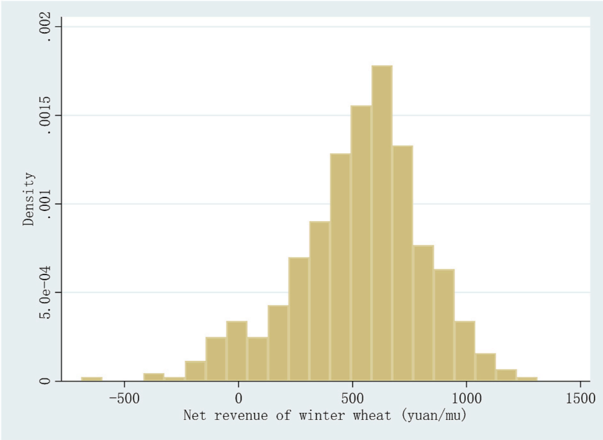

Fig. B1. Distribution of farmers' net revenue of winter wheat Note: The data source is the survey

Table B1
Fractional factorial design of choice experiment

Compensation	Fallow duration	Employment support	Green manure fallow	Choice set	Alternative
300	5	Provided	Not required	1	1
300	3	Not provided	Required	1	2
Opt-out				1	3
300	5	Not provided	Required	2	1
300	1	Not provided	Not required	2	2
Opt-out				2	3
500	3	Not provided	Not required	3	1
500	5	Provided	Required	3	2
Opt-out				3	3
500	1	Provided	Not required	4	1
700	3	Provided	Required	4	2
Opt-out				4	3
700	1	Not provided	Required	5	1
500	1	Provided	Not required	5	2
Opt-out				5	3
700	3	Provided	Required	6	1
700	5	Not provided	Not required	6	2
Opt-out				6	3

Table B2
Pictural Example of choice set

	Option 1	Option 2	Option 3
Compensation			Opt-out
Fallow duration	One year	Five years	

(continued on next page)

Table B2 (*continued*)

	Option 1	Option 2	Option 3
Employment support	None		
Green manure fallow			

Appendix C. Supplementary model results

Table C1
Regression results of conditional logit model

	Model 1	Model 2
	full samples	full samples with interactions
Compensation	0.009***	0.009***
	(0.000)	(0.000)
Fallow duration	0.13***	0.15***
	(0.02)	(0.02)
Employment support	0.29***	0.26***
	(0.05)	(0.05)
Green manure fallow	−0.32***	−0.43***
	(0.05)	(0.05)
ASC	−5.38***	−5.50***
	(0.38)	(0.39)
Interactions of farm size with		
Compensation		0.000
		(0.000)
Fallow duration		−0.08**
		(0.04)
Employment support		0.14
		(0.11)
Green manure fallow		0.51***
		(0.11)
Interactions of ASC	Yes	Yes
Observations	12,888	12,888
Log likelihood	−3591	−3571
AIC	7208	7176
BIC	7305	7303
LR $\chi 2$	2258	2297
McFadden's R^2	0.24	0.24

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. The interactions of ASC include interactions with the eight variables of farmers' features described in Table 2. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. SFs = Small-scale farmers, LFs = Large-scale farmers.

Table C2
Regression results of latent class model

	Model 1			
	Class1	Class2	Class3	Class4
Compensation	0.02***	0.02***	0.02***	0.02***
	(0.001)	(0.001)	(0.001)	(0.001)
Fallow duration	0.39	−0.31***	0.22***	0.20***
	(0.69)	(0.07)	(0.03)	(0.03)
Employment support	0.93	1.16***	0.47***	0.64***
	(1.61)	(0.22)	(0.10)	(0.10)
Green manured fallow	−1.89	−4.33***	0.17*	−0.35***
	(1.96)	(0.24)	(0.09)	(0.11)
ASC	−14.94***	−5.23***	15.27	−8.84***
	(3.55)	(0.28)	(1226.38)	(0.30)
Constant	−2.05***	−1.27***	−0.90***	
	(0.16)	(0.12)	(0.10)	
Observations	12,888			
Log likelihood	−2854			
AIC	5754			
BIC	5925			
Class share	0.07	0.16	0.22	0.55
	Model 2			
	Class1	Class2	Class3	Class4
Compensation	0.02***	0.02***	0.02***	0.02***
	(0.001)	(0.001)	(0.001)	(0.001)
Fallow duration	0.32	−0.31***	0.22***	0.20***
	(0.67)	(0.07)	(0.03)	(0.03)
Employment support	0.78	1.15***	0.47***	0.65***
	(1.52)	(0.22)	(0.10)	(0.10)
Green manured fallow	−1.91	−4.34***	0.17*	−0.35***
	(1.84)	(0.24)	(0.09)	(0.10)
ASC	−14.59***	−5.24***	15.73	−8.84***
	(3.45)	(0.28)	(1359.08)	(0.30)
Membership: farm size	−0.59	−1.25***	−0.51**	
	(0.39)	(0.37)	(0.24)	
Constant	−1.91***	−1.05***	−0.79***	
	(0.18)	(0.13)	(0.11)	
Observations	12,888			
Log likelihood	−2854			
AIC	5754			
BIC	5925			
Class share	0.07	0.16	0.22	0.55

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. In Model 1, only the attributes (or supporting measures are) included in the model. In Model 2, we include the dummy variable representing farm size (1 indicating large-scale farmers and 0 otherwise) as the only class membership variable since we focus on exploring the heterogeneity of operated farmlands.

Table C3
Regression results of the mixed logit model using the random form of compensation variable

	Model 1		Model 2		Model 3	
	Full samples		SFs samples		LFs samples	
	Coef.	Std.dev.	Coef.	Std.dev.	Coef.	Std.dev.
Compensation	0.02***	0.002	0.02***	0.002	0.02***	0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Fallow duration	0.14***	0.31***	0.15***	0.38***	0.10*	0.02
	(0.03)	(0.06)	(0.03)	(0.05)	(0.05)	(0.07)
Employment support	0.74***	1.10***	0.68***	1.11***	1.00***	1.16***
	(0.08)	(0.13)	(0.10)	(0.16)	(0.19)	(0.29)
Green manure fallow	−1.09***	2.51***	−1.32***	2.62***	−0.33	1.97***
	(0.14)	(0.18)	(0.17)	(0.21)	(0.23)	(0.30)
ASC	−10.43***	2.96***	−9.99***	3.09***	−10.01***	2.48***
	(1.30)	(0.22)	(1.62)	(0.26)	(2.68)	(0.42)
Interactions of ASC	Yes		Yes		Yes	
Observations	12,888		10,044		2844	
Log likelihood	−2961		−2327		−609	
AIC	5959		4649		1253	
BIC	6093		4820.		1360	
Wald $\chi 2$ (13)	449		334		120	

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. Coef. = Coefficient, Std.dev. = standard deviation, SFs = Small-scale farmers, LFs = Large-scale farmers.

Table C4
Regression results of the mixed logit model using the lognormally distributed form of compensation variable

	Model 1		Model 2		Model 3	
	Full samples		SFs samples		LFs samples	
	Mean	Std.dev.	Mean	Std.dev.	Mean	Std.dev.
Compensation (Ln.coef.)	−3.88***	0.11***	−3.89***	0.05	−3.88***	0.08
	(0.05)	(0.02)	(0.06)	(0.05)	(0.10)	(0.05)
Fallow duration	0.13***	0.32***	0.15***	0.38***	0.10*	0.07
	(0.03)	(0.05)	(0.03)	(0.05)	(0.05)	(0.08)
Employment support	0.77***	1.11***	0.66***	1.10***	1.00***	1.14***
	(0.09)	(0.14)	(0.10)	(0.16)	(0.19)	(0.28)
Green manure fallow	−1.10***	2.51***	−1.29***	2.57***	−0.37	1.96***
	(0.14)	(0.18)	(0.17)	(0.20)	(0.23)	(0.30)
ASC	−10.56***	2.94***	−10.06***	3.11***	−10.49***	2.55***
	(1.28)	(0.22)	(1.59)	(0.28)	(3.00)	(0.40)
Interactions of ASC	Yes		Yes		Yes	
Observations	12,888		10,044		2844	
Log likelihood	−2961		−2328		−608	
AIC	5960		4691		1252	
BIC	6092		4821		1359	
Wald χ2 (13)	125,625		89,853		34,944	

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. Coef. = Coefficient, Std.dev. = standard deviation, SFs = Small-scale farmers, LFs = Large-scale farmers.

Table C5
Regression results of mixed logit model including the fallow duration squared term

	Model 1		Model 2		Model 3	
	Full samples		SFs samples		LFs samples	
	Coef.	Std.dev.	Coef.	Std.dev.	Coef.	Std.dev.
Subsidy	0.02***		0.02***		0.02***	
	(0.001)		(0.002)		(0.003)	
Fallow duration	−0.55***	1.12***	−0.46**	0.93***	−0.19	0.18
	(0.17)	(0.22)	(0.18)	(0.25)	(0.40)	(1.32)
Fallow duration squared term	0.11***	0.05***	0.10***	0.07***	0.06	0.01
	(0.03)	(0.01)	(0.03)	(0.01)	(0.06)	(0.02)
Employment support	0.79***	0.13	0.71***	0.29	1.13***	1.00**
	(0.12)	(0.39)	(0.13)	(0.23)	(0.29)	(0.45)
Green manured fallow	−0.79***	1.77***	−1.07***	1.60***	−0.16	1.78**
	(0.16)	(0.28)	(0.19)	(0.25)	(0.39)	(0.7 4)
ASC	−10.93***	3.76***	−10.81***	3.90***	−10.80***	3.38***
	(1.42)	(0.33)	(1.81)	(0.39)	(2.86)	(0.69)
Interactions of ASC	Yes		Yes		Yes	
Observations	12,888		10,044		2844	
Log likelihood	−2903		−2272		−600	
AIC	5865		4601		1259	
BIC	6081		4811		1432	
Wald χ2	326		240		108	

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. The interactions of ASC include interactions with the eight variables of farmers' features described in Table 2. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. Coef. = Coefficient, Std.dev. = standard deviation, SFs = Small-scale farmers, LFs = Large-scale farmer.

Table C6
Mixed logit model with corrected parameters by farmers kinds and by participation experience

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Full samples		SFs Samples		LFs Samples	
	Non-participants	Participants	Non-participants	Participants	Non-participants	Participants
Coef.						
Compensation	0.02***	0.02***	0.02***	0.02***	0.02***	0.02***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.002)
Fallow duration	0.09**	0.30***	0.07	0.32***	0.12	0.21**
	(0.05)	(0.05)	(0.05)	(0.06)	(0.13)	(0.10)
Employment support	0.63***	0.81***	0.58***	0.77***	1.10**	1.06***

(continued on next page)

Table C6 (*continued*)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Full samples		SFs Samples		LFs Samples	
	Non-participants	Participants	Non-participants	Participants	Non-participants	Participants
	(0.14)	(0.14)	(0.14)	(0.17)	(0.46)	(0.29)
Green manure fallow	−0.93***	−0.83***	−1.11***	−1.01***	−0.13	−0.46
	(0.19)	(0.19)	(0.21)	(0.24)	(0.58)	(0.32)
ASC	−10.16***	−12.23***	−9.94***	−11.09***	−3.55	−13.34***
	(1.83)	(1.91)	(1.94)	(2.88)	(5.30)	(2.73)
Std.dev.						
Fallow duration	0.33***	0.39***	0.36***	0.45***	0.20	0.31***
	(0.06)	(0.06)	(0.06)	(0.07)	(0.16)	(0.10)
Employment support	0.91***	1.25***	0.91***	1.29***	1.13*	0.67
	(0.20)	(0.18)	(0.21)	(0.20)	(0.60)	(0.44)
Green manure fallow	−1.10**	1.25***	0.93**	0.87	0.92	1.30*
	(0.45)	(0.42)	(0.46)	(0.95)	(0.70)	(0.68)
ASC	3.55***	3.35***	3.41***	3.57***	4.23***	2.96***
	(0.34)	(0.35)	(0.36)	(0.44)	(1.14)	(0.63)
Interactions of ASC	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12,888	12,888	5598	4446	936	1908
Log likelihood	−1496	−1411	−1284	−995	−193	−380
AIC	3039	2868	2614	2036	431	806
BIC	3195	3023	2767	2185	543	933
LR $\chi 2$	760	545	625	477	114	79
McFadden's R-squared	0.20	0.16	0.19	0.18	0.21	0.07

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. The interactions of ASC include interactions with the eight variables of farmers' features described in Table 2. AIC = Akaike Information Criterion, BIC=Bayesian Information Criterion. Coef. = Coefficient, Std.dev. = standard deviation, SFs = Small-scale farmers, LFs = Large-scale farmers.

Appendix D. Data, model, and estimation results of contingent valuation method

In the CVM survey, respondents were asked if they would participate in the program under a given compensation, using multiple bounded dichotomous questions. A dichotomous choice question was followed by a second question with a significantly higher or lower amount. The questionnaire set three starting points: 200, 500, and 800 yuan/mu/year, with a range from 100 to 900 yuan/mu/year. If respondents answered positively, they were asked about a higher amount (300, 600, or 900 yuan); if negative, a lower amount (100, 400, or 700 yuan). Respondents were randomly divided into three groups, each starting from a different initial bid. The probit model is used to model how fallow decisions respond to compensation level attributes which is presented below:

$$V_{in}^{*} = \beta^{*} c_n + F_i{}^{*}\alpha + \mu_{in} \tag{1a}$$

where V_{in}^{*} is a latent variable, c_n is the n different amounts offered to farmer i for each mu of fallowed land per year, F_i is a vector of characteristics at the individual farmer level, β is a parameter and α is a vector of parameters to be estimated, and μ_{in} is a random error term. The link between the observed binary variable for fallow decision y_{in} and the latent V_{in}^{*} is expressed as:

$$V_{in} = \begin{cases} 1, if\ V_{in}^{*} > 0 \\ 0, if\ V_{in}^{*} \leq 0 \end{cases} \tag{2a}$$

where $V_{in} = 1$ if farmer i indicated he or she would fallow at compensation level n and $V_{in} = 0$ otherwise. The WTA of each farmer i in this case can be described as:

$$WTA_i = -\frac{1}{\widehat{\beta}}(\widehat{\mu} + F_i{}^{*}\widehat{\alpha}) \tag{3a}$$

The F_i variables we include in the model is the same with the variables in the CE model. Let the F_i equal the mean of the F_i, then we can get the mean of the WTA. Table D1 presents CVM estimate.

Table D1
Probit regression results under the CVM method

	Model 1	Model 2	Model 3
	Full samples	SFs samples	LFs samples
Compensation	0.006***	0.006***	0.007***
	(0.001)	(0.001)	(0.001)

(*continued on next page*)

Table D1 (*continued*)

	Model 1	Model 2	Model 3
	Full samples	SFs samples	LFs samples
Age	0.02***	0.02***	−0.01
	(0.003)	(0.003)	(0.006)
Gender	0.19**	0.15	0.33
	(0.09)	(0.10)	(0.20)
Education	0.04***	0.04***	0.06***
	(0.008)	(0.009)	(0.023)
Non-farm experience	0.13***	0.18***	−0.05
	(0.05)	(0.06)	(0.10)
Risk attitude	−0.004	−0.02*	0.04***
	(0.007)	(0.008)	(0.02)
Asset	0.18***	0.18***	0.15*
	(0.05)	(0.06)	(0.08)
Water-saving irrigation	−0.29***	−0.29***	−0.31*
	(0.05)	(0.06)	(0.16)
Well depth	0.06***	0.07***	−0.01
	(0.02)	(0.02)	(0.07)
Constant	−3.89***	−3.93***	−3.93***
	(0.21)	(0.24)	(0.50)
Observations	6444	5022	1422
LR $\chi 2$	4818	3665	1184
Log likelihood	−2034	−1630	−388
Pseudo R^2	0.54	0.53	0.61

Note: * p-value <0.10, ** p-value <0.05, *** p-value <0.01. Standard errors are in parentheses. SFs = Small-scale farmers, LFs = Large-scale farmers.

Data availability

The authors do not have permission to share data.

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