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Small farmer's planting confidence and willingness to pay for leguminous green fertilizer: environmental attributes perspective

RESEARCH ARTICLE

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Abstract

To evaluate whether small farmers are willing to accept the policy of sustainable use of cultivated land such as green manure planting, we analyze the payment preference and the source of heterogeneity of small farmer's environmental attributes of leguminous green manure. A choice experiment method is conducted to learn about small farmer's preference toward green manure. The results suggest that small farmers with planting confidence are willing to pay for different environmental attributes of leguminous green manure. Among them, the willingness to pay (WTP) for the quality and fertility of cultivated land is the highest, and the WTP for air quality is the lowest. Small farmers who do not have confidence in planting are only willing to pay for attribute of natural disaster days. We identify key factors that might influence small farmer's payment preference, including gender, age, education level, degree of part-time employment, and the trend perception of environmental change.

Keywords: leguminous green fertilizer, willingness to pay, choice experiment method, small farmer
JEL code: Q18

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1. Introduction

Intensive agriculture with high inputs has promoted China's productivity growth (Shen *et al.*, 2019). Chinese farmers have formed a production method with excessive chemical fertilizers (Cheng *et al.*, 2020; Sun *et al.*, 2019). This has caused serious agricultural non-point source pollution problems, threatened the circular green and sustainable development of China's agriculture (Evans *et al.*, 2019; Luo *et al.*, 2016; Sun *et al.*, 2019; Tang *et al.*, 2019; Zou *et al.*, 2020). The Chinese government has taken many measures to promote the reduction of chemical fertilizer input, such as the 'Zero-Growth Action on Fertilizer (ZGAF)' (the Ministry of Agriculture and Rural Affairs of China P.R., 2015b) in 2015. In 2017, the government further proposed expanding the ZGAF and carrying out the pilot program of replacing chemical fertilizers with organic fertilizers in 'No. 1 Central Document' (The Central Committee of the Communist Party of China and the State Council, 2017).

Green manure is an economical, practical, and effective organic fertilizer (Li *et al.*, 2020a). It can not only provide nutrients for crops but also has environmental benefits such as soil improvement, nitrogen fixation, and carbon absorption, water and fertilizer conservation (Adnan *et al.*, 2019; Tambo and Mockshell, 2018; Zhang *et al.*, 2016, 2019). It is an effective way to improve China's agricultural resource and environmental problems (Li and Shen, 2021) and realize a food crop production strategy based on farmland management and technological application. How to effectively promote green manure planting has become a common concern of the government and academia.

As an important stakeholder in the green manure planting policy, farmer's decision-making will affect the realization of the environmental value of agricultural products and the sustainable development of agriculture (David *et al.*, 2020; Li *et al.*, 2020b). When the government formulates relevant incentive policies, farmer's individual differences and preferences should be fully considered. However, few studies have examined environmental attributes' perception of green manure. Li and Shen (2021), Wang *et al.* (2016), Lu *et al.* (2019) discussed the willingness and degree of farmer's acceptance of organic fertilizer application through binary discrete models. Some research analyzed the main factors affecting farmer's willingness to use organic fertilizer, such as environmental perception, risk preference, economic conditions, labor force (Bopp *et al.*, 2019; Hijbeek *et al.*, 2019; Liu *et al.*, 2019; Wang *et al.*, 2018; Yu *et al.*, 2021). Other studies did a survey to understand farmer's judgments on expected income, surrounding location conditions, and environmental resource conditions, use contingent valuation method to evaluate the benefits of organic fertilizers (Kousar and Abdulai, 2016; Krah *et al.*, 2019).

There are still some gaps in the existing research. First of all, few studies have focused on small farmer's organic planting preference. According to data released by the Ministry of Agriculture and Rural Affairs of the People's Republic of China, to the end of 2016, there are still nearly 260 million small farmers in the country, accounting for about 97% of the total number (Qu, 2017). As the main body of agricultural production and management activities, small farmers have direct decision-making power on green fertilizer planting. Secondly, existing studies mainly focused on the impact of farmer's socio-economic characteristics on their green fertilizer application behavior and economic analysis, ignoring farmer's psychological characteristics, such as planting confidence. However, confidence is crucial to farmer's decision-making (Castillo *et al.*, 2021; Robyn *et al.*, 2018). Most previous studies focused on that financial (increased costs or foregone income) and effect perception, which are the main obstacles affecting farmer's adoption of green technologies (Hijbeek *et al.*, 2019; Li and Li, 2020). Therefore, this study uses whether small farmers are worried that green manure planting will reduce income to measure their planting confidence. According to Table 1, the net benefit of green manure is relatively lower than those of chemical fertilizer and organic fertilizer, but the range is acceptable. Considering the long-term ecosystem benefits, it shows that leguminous green manure is a better choice. Lastly, existing studies have not examined small farmer's willingness to pay (WTP) for different environmental attributes of leguminous green manure. Compared with non-leguminous green manure, leguminous green manure also affects fixing nitrogen in the air. Its gas regulation and nitrogen

Table 1. Costs and benefits of wheat under different fertilizer application.[1]

Categories	Costs (yuan/mu)	Yields (kg/mu)	Benefits (yuan/mu)	Net benefits (yuan/mu)
Chemical fertilizers (Li *et al.*, 2021)	107.07	492.53	1,039.25	932.18
Organic fertilizer (80%) (Li *et al.*, 2021)	234.75	521.33	1,100.01	865.26
Leguminous green manure	115 (Li and Yin, 2019)	459.73	970.03	855.03 (Zhang *et al.*, 2011)

[1] The data in the table are calculated according to the unified price standard and the net income here only refers to the income minus the cost of fertilizer.

fertilizer supply capabilities are better (Zhang *et al.*, 2016). Considering the physical geography and the current status of leguminous green manure planting in the study area, the intercropping mode is selected.

This paper uses the choice experiment method to investigate small farmer's WTP for the environmental attributes of leguminous green manure. It also analyzes the payment preferences and influencing factors for environmental attributes from socio-economic characteristics, psychological and environmental change perception.

The succeeding section are as follows. Section 2 constructs a theoretical framework and puts forward research hypotheses. Section 3 presents research data and methods, including experimental design, data collection, and econometric model. Section 4 presents the results and robustness tests. Finally, Section 5 concludes the paper.

2. Theoretical framework

Although the Chinese government has stepped up efforts to promote leguminous green manure planting, it did not achieve the desired results. In reality, the worry about the yield of intercropping leguminous green manure is the main reason that small farmers are unwilling to adopt it (Baqir *et al.*, 2016; TerAvest *et al.*, 2019). In a short period, this situation may occur, but the long-period application of chemical fertilizers will bring huge and unrecoverable damage to the environment (Madembo *et al.*, 2020). As a result, the economic benefits of small farmers will inevitably decrease. Therefore, the correct cognition and preference of leguminous green manure's environmental attributes will help its widespread promotion. The key to this problem is to clarify the influencing factors that affect small farmer's perception of leguminous green manure's environmental attributes.

The theory of 'rational small farmers' believes that whether small farmers can make rational decisions for the greatest benefit depends on internal factors and their external environment. (Schultz, 1964). In practice, when making decisions about leguminous green manure planting, small farmers must measure the benefits before and after plant. Intercropping with leguminous green manure and wheat will increase costs, reduce returns, and affect small farmer's income and profits, ultimately affecting their maximum utility (Li *et al.*, 2020a). Therefore, small farmer's planting confidence is particularly important (Figure 1), which directly affects their decision-making and willingness to participate in leguminous green manure planting. Since agricultural production investment decisions are determined by production and consumption, small farmer's WTP will also be affected by variables that affect production and consumption preferences. The preference for different environmental attributes of leguminous green manure will be a function of their characteristics. For example, gaining effective confidence will affect their agricultural planting knowledge, attitude, and perception, which is important driving forces for decision-making. Besides, the family's economic level is also the main factor affecting their WTP. Based on this, this study takes the 'social and economic characteristics' and 'perception of technological and environmental changes' of small farmers as the main factors affecting their WTP.

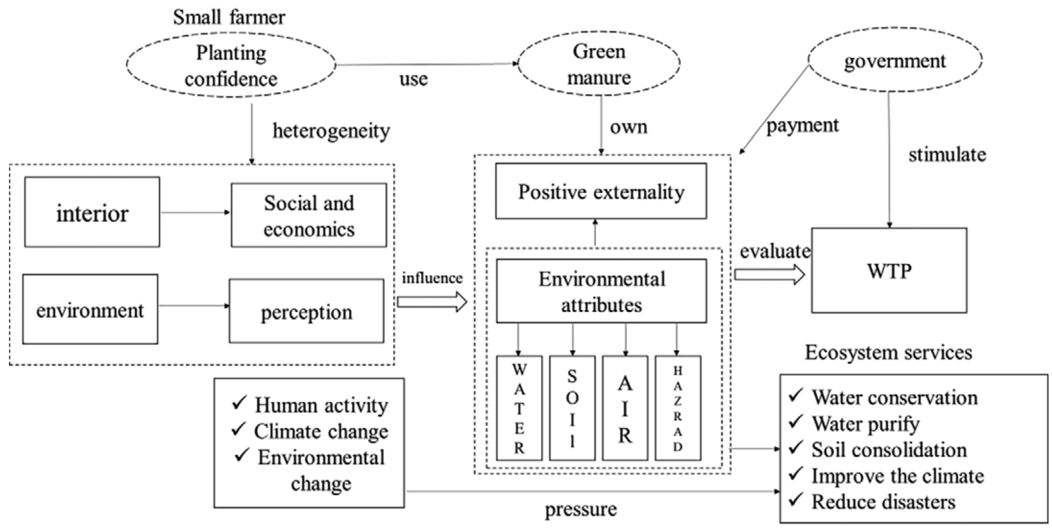

Figure 1. Analytical framework.

Figure 2 assumes that only small farmer's choices between two attributes in production are considered: environmental attributes (such as water quality, etc.) and economic attributes (such as output value and cost, etc.). D_1, D_2, D_3 represent different types of production technologies such as chemical fertilizers, leguminous green manure, biological fertilizers, β_1, β_2 and β_3 are the ratios of environmental attributes of each technology. It can be seen that technology 1 improves economic attributes more significantly than technology 3, while technology 3 has more advantages in improving environmental attributes. The composition of the two attributes in technology 2 is between technology 1 and technology 3. In the figure, U_0 is the expected utility level of small farmers before fertilization, and B_0 is the budget line. To achieve the expected utility level under a given budget line, small farmers will choose technology D_2 for fertilization. That is, choose the ratio of water quality and cultivated land quality of the combination of G_0 and C_0 to achieve a consumption balance at point E_0, achieve the expected utility level U_0 (when these two environmental attributes are substitution relationships) or U_1 (when these two environmental attributes are complementary relationship).

Specifically, at E_0, the marginal substitution rate (*MRS*) of the two environmental attributes is exactly equal to the slope of the budget line. Because there are some differences in the preferences of each small farmer, some of them may regard the two attributes as substitutes (solid indifference curve U_0). In comparison, others may regard the two attributes as complementary products (dashed indifference curve U'_0). The preference of small farmers for attributes will directly affect the demand for fertilization technology. Before production, if

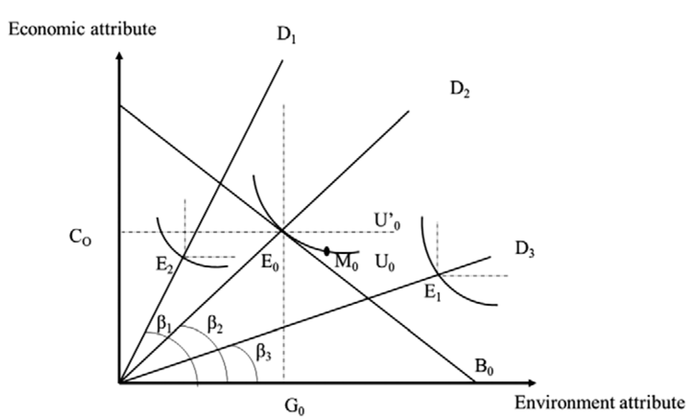

Figure 2. Small farmer's fertilizer preference.

small farmers learned leguminous green manure could not achieve his environmental preference by existing information, they will not choose leguminous green manure planting. Secondly, when small farmers do not fully understand leguminous green manure's environmental attributes, they may choose to apply leguminous green manure. However, when small farmers plant leguminous green manure and find that their environmental attributes do not meet the requirements of their personal utility, the situation will appear: For them who believe that environmental attributes and economic attributes have a substitute relationship, they can choose M_0 fertilization behavior, make the environmental attributes are better, but the economic attributes are poor, to continue to maintain its expected utility level. There is another possible situation: small farmers who think that the attributes are complementary will choose other production technologies. Obviously, without exogenous constraints, the latter is based on the leguminous green manure planting theory that constitutes the attribute preference of small farmers.

Since small farmers achieve the maximum utility at E_0, that is, the consumer surplus ($\sum(MWTP\text{–}P)$) of them reaches the maximum, as shown in the shadow part of Figure 3. In Figure 3, when the price of leguminous green manure is equal to the marginal WTP (MWTP), the consumer surplus reaches the maximum, and its corresponding Q_1 is the critical value of environmental attributes acceptable to small farmers (that is, at a given price level of leguminous green manure, the level of environmental attributes that small farmers are willing to accept). Therefore, the WTP for leguminous green manure based on environmental attributes is to find the best environmental attribute level that small farmers are willing to accept. So, as long as you find the MWTP function and make it equal to the price of leguminous green manure, the critical value of environmental attributes can be obtained. For small farmers who are confident in planting, their purchase of leguminous green manure is relatively inelastic. Therefore, the consumer surplus of these small farmers will increase (Figure 3), and the excess is the change in MWTP.

Based on the above analysis, we propose the hypothesis: farmers with planting confidence are more willing to pay for the environmental attributes of leguminous green manure.

3. Materials and methods

3.1 Experimental design

In a choice experiment (CE), the attributes determine the commodity (Liu, 2019). By constructing a hypothetical market, consumers are provided with a choice set composed of different attribute levels attached to a product. Based on the size of their personal utility of different options, consumers choose their favorite option and indirectly measure the economic value (Tur-Cardona *et al.*, 2018). Excessive application of chemical fertilizers has caused damage to the environment, such as water pollution, increased greenhouse gases, and decreased cultivated land quality (Cheng *et al.*, 2020; Luo *et al.*, 2014; Peth *et al.*, 2018; Wang *et al.*, 2017; Zhou *et al.*, 2020). Replacing some chemical fertilizers with leguminous green manure can effectively improve the ecological environment and enhance sustainable agricultural development. (Aryal, *et al.*, 2016; Li *et al.*, 2020; Panos *et al.*, 2015; Tarfasa *et al.*, 2018), combined with expert advice and information obtained by the pre-survey, we finally determined the environmental attributes that can be improved by the cultivated

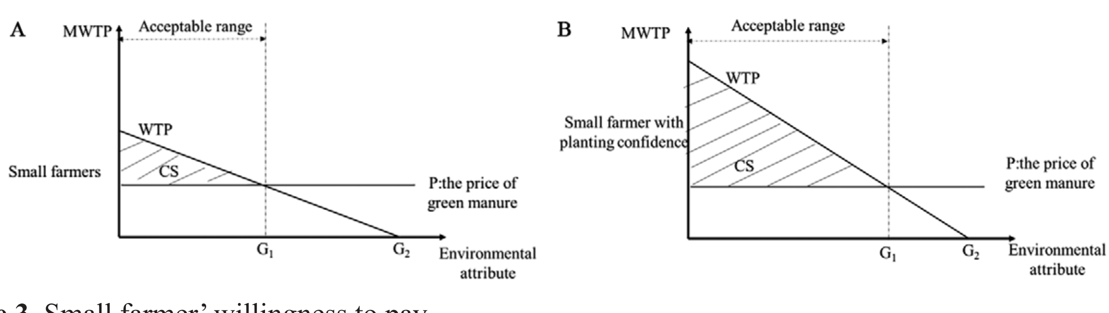

Figure 3. Small farmer' willingness to pay.

land ecosystem after planting leguminous green manure that small farmers are most concerned about. The chosen attributes and corresponding levels are as follows (Table 2):

- Water quality. According to the data from the 'China Ecological Environment Statement' (Ministry of Ecology and Environment of the People's Republic of China, 2019), we set the water quality of Class V as the baseline level of agricultural irrigation water used in the study area at present or in the future and select the improvement level as Class IV and III water quality.
- Cultivated land quality and fertility. As the study areas located in the main wheat-producing areas, the fertility of the cultivated land is good. Refer to the 'China Land and Resources Statement' (Ministry of Natural Resources of the People's Republic of China, 2017) and the 'Sustainable Agricultural Development Plan' (Ministry of Agriculture and Rural Affairs of the People's Republic of China, 2015), we choose the national average quality grade of cultivated land as the baseline level and improve 1 grade, and 2 grades are selected as the improvement level.
- Air quality. According to the air quality report published by the environmental protection department, we take the number of days with excellent and good air as the standard to measure air quality and take the ratio of the number of days with excellent and good air in the study area in 2018 as the baseline level (Ministry of Ecology and Environment of the People's Republic of China, 2019). The improvement level is selected as the number of days with excellent and good air increased by 10 and 5% respectively.
- Days of the natural disaster. Widespread cultivation of leguminous green manure can reduce the intensity of agricultural greenhouse gas emissions and reduce the incidence of natural disasters caused by excessive greenhouse gas emissions. From the studies on climate change, most scholars obtained the data from at least last 3 years (Nguyen and Leisz, 2021; Wheeler *et al.*, 2021). Therefore, according to 'China Ecological Environment Statement', we use the number of natural disaster days in the study area in 2018 as the baseline level. The improvement level is selected as a reduction of 5 and 10% in the number of natural disaster days.
- Payment amount. In terms of cost expenditure, we set 5 levels of '0 yuan/mu[1], 50 yuan/mu, 100 yuan/mu, 150 yuan/mu, 200 yuan/mu' based on the cost of green manure planting and the recommendations of relevant agricultural experts. In this way, the WTP of small farmers for intercropping leguminous green manure is measured.

[1] 1 mu = 0.165 acre.

Table 2. Attributes and levels.

Attributes	Descriptions	Levels
Water quality	The average quality of agricultural irrigation water	• Class V • Class IV • Class III
Cultivated land quality and fertility	The average quality grade of cultivated land	• No change • Improve 1 grade • Improve 2 grade
Air quality	Number of days with excellent and good air quality	• No change • Increase 5% • Increase 10%
Days of natural disaster	Days of natural disasters such as droughts, floods, and cold snaps throughout the year	• No change • Reduce 5% • Reduce 10%
Payment amount (yuan/mu)	The amount that small farmers are willing to pay for one hectare of leguminous green manure and wheat intercropping	• 0 • 50 • 100 • 150 • 200

Based on the setting of the environmental attributes and levels of leguminous green manure, a total of 3×3×3×3×5=405 experimental options can be produced. If these options are submitted to the respondent, the questionnaire will be too cumbersome, and some unreasonable settings also exist in these options, which may affect the results of the experiment. Considering the feasibility of actual operation, we used JMP software to carry out an orthogonal design (JMP, Cary, NC, USA). In design, the D-efficiency criterion is used to identify the best combination of choice sets, resulting in a CE with 6 choice sets. In each choice set, small farmers were presented with three options (two (A and B) improvement options and one benchmark option). A sample choice set is listed in Table 3.

3.2 Data collection

The research data came from the survey of the WTP for green manure of small wheat farmers conducted by the research team in Henan, Shandong, Anhui, Hebei, and Jiangsu provinces from July to September 2019. The reasons for the study area selection as follows: First, Henan, Shandong, Anhui, Hebei, and Jiangsu are important wheat planting regions in China and their output ranks among the top 5; Secondly, wheat production is vulnerable to environmental changes. Its yield and quality instability has increased under the background of increasing climate change. In this situation, this study believes that the field survey of wheat small farmers in these provinces, the difficulty of popularizing knowledge about environmental changes is relatively low, and the survey data is also representative.

The survey used stratified random sampling. First, randomly select 1 to 2 counties (districts) from 5 provinces; next, select 2 to 3 towns within each county (district); then each town selected 2 to 4 administrative villages; finally, about 30 small farmers engaged in wheat planting were randomly selected in each administrative village, and interviews were conducted with the head of the household or the main agricultural labor force of the family.

3.3 Econometric model

The CE builds on Lancaster's consumer choice theory, according to which utility comes from the attributes attached to the commodity, not the commodity itself (Lancaster, 1966). The relevant empirical analysis is based on McFadden's random utility theory, which believes that consumers will make utility maximization choices based on the level of product characteristics and their own characteristics (McFadden, 1974). According to the random utility theory, in this CE, the utility obtained by small farmers can be divided into two parts, one is the observable deterministic utility brought about by the environmental attributes of leguminous green manure, and the other is the unobservable utility. The specific model of the random utility of is as follows:

$$U_{ni} = V_{ni} + \varepsilon_{ni} \quad (1)$$

Where U_{ni} represents the overall utility when small farmer n choose option i. V_{ni} represents the observable utility when small farmer n choose option i. ε_{ni} is the random error term that represents the unobservable utility.

Table 3. A sample choice set in choice experiment surveys.

Attributes	**Option A**	**Option B**	**Option C**
Water quality	Class III	Class III	No change
Cultivated land quality and fertility	Improve 2 grade	Improve 1 grade	No change
Air quality	Increase 10%	Increase 5%	No change
Days of natural disaster	Reduce 10%	Reduce 5%	No change
Payment amount	200 yuan/mu	150 yuan/mu	0 yuan/mu
I would choose option	☐	☐	☐

Assuming the rationality of small farmers, they choose option *i* instead of *j* from the specified choice set need to satisfy $U_{ni} > U_{ij}$, and the specific probability P_{ni} expression is as follows:

$$P_{ni} = P(U_{ni} > U_{nj}) = P(V_{ni} + \varepsilon_{ni} > V_{nj} + \varepsilon_{nj}), \forall i \neq j \quad (2)$$

In order to obtain the specific expression formula of the model, we assume that the error term is identically and independently distributed with an Extreme Value Type I (Gumbel) distribution. Multinomial logit models (MNL) can be obtained. The general probability form of small farmers *n* choosing option *j* is:

$$P_{ni} = \frac{\exp(v_{ni})}{\sum_{j=1}^{i} \exp(v_{nj})} \quad (3)$$

In such cases utility takes the form as follows:

$$U_{ni} = ASC_i + \beta_i X_{ni} + \beta_m \times ASC_i \times S_{nm} + \beta_1 \times ASC_i \times P_{nl} + \varepsilon_{ni} \quad (4)$$

$$U_{ni} = ASC_i + \beta_i X_{ni} + \beta_m \times ASC_i \times S_{nm} + \beta_1 \times ASC_i \times P_{nl} + ASC_i \times \beta_v D_{nv} + \varepsilon_{ni} \quad (5)$$

Where ASC_i stands for an option specific constant for option *i* which captures the average effect of unobserved factors on utility. X_{ni} are the attributes of option *i* selected by small farmer *n*, β_i is the vector of coefficients associated with each attribute of option *i*. S_i and P_{nl} are the socio-economic, technological and environmental change perception characteristics of individual *n*, β_m and β_l are the vector of coefficients of interactions between the alternative specific constant (ASC) and the socio-economic, technological and environmental change perception characteristics of the individual. D_{nv} are the province dummy variables, β_v is the vector of coefficients associated with each province.

By using the maximum likelihood estimation method, the marginal WTP for leguminous green manure environmental attributes of small farmers can be obtained, which can be expressed as:

$$WTP = -\frac{\beta_i}{\beta_p} \quad (6)$$

Where β_i is the coefficients of leguminous green manure environmental attributes, β_p is the coefficient of the payment amount attribute.

4. Empirical results

4.1 Data description statistics

After excluding some invalid questionnaires, we finally obtain 1,209 valid observations. The effective ratio is 94.08%. Table 4 presents the summary statistics. From the perspective of the socio-economic characteristics of the sample, 63% of the respondents are male. The average age is 47.51. In terms of risk preference, 46% of the respondents are risk aversion, their average years of education are 7.71 years, and their total household income is about 50,500 yuan per year. In the sample, the respondents are mainly part-time type II, accounting for 37%. From the perspective of technology and environmental change perceptions, only 22% of respondents said they had received relevant technical training. 33% of the respondents felt the deterioration of the local environment. Among the 1,209 small farmers interviewed, 70% expressed confidence in the leguminous green manure planting. They believed that intercropping leguminous green manure could improve the local ecological environment while ensuring wheat production. Besides, due to a variety of restrictive factors, 30% of small farmers expressed have no confidence in leguminous green manure planting.

Table 4. Descriptive statistics.

Variables	Variable description	Mean	Std. Dev[1]
Socio-economic characteristics			
Gender	female=0, male=1	0.63	0.48
Age	age of respondents	47.51	10.05
Risk preference	aversion=1, neutral=2, preference=3	1.78	0.81
Education level	respondent's years of education (year)	7.71	1.76
Total annual income	family annual income (10,000 yuan)	5.05	1.11
Part-time degree	non-farmers=1, part-time type II=2, part-time type I=3, pure farmer=4	2.29	1.04
Technology and environmental change perception			
Related technical training	never participated=0, participated=1	0.22	0.41
Environmental change perception	improve=1, smooth=2, deteriorate=3	2.26	0.58
Planting confidence			
Leguminous green manure planting confidence	without=0, have=1	0.70	0.46
Province dummy variables (Henan as control group)			
Hebei	no=0, yes=1	0.29	0.46
Shandong	no=0, yes=1	0.19	0.39
Anhui	no=0, yes=1	0.20	0.40
Jiangsu	no=0, yes=1	0.12	0.33

[1] Std. Dev = standard deviation.

4.2 Econometric results

In this paper, the samples are divided into two types according to the differences in planting confidence. We use Stata 15.0 software (StataCorp LLC, College Station, TX, USA) to estimate the two forms of the MNL model, compare and analyze the differences in environmental attribute preferences of different small farmers for leguminous green manure. In this part, we establish a total of 4 models (Table 5). Among them, Model 1 and Model 3 are the basic models, which only include the attribute variables and the ASC; Model 2 and Model 4 introduce the socio-economic, technological, and environmental change perception characteristics of selected small farmers based on Model 1 and Model 3 respectively. The results are shown in Table 5.

From the results, the models all pass the significance test. Model 2 and Model 4 introduce the socio-economic, technological and environmental change perception characteristics of small farmers. They have more information to explain the results, so we mainly analyze these two models' estimation results. The main results are as follows:

The two models' ASC coefficients are both significantly negative at the 1% level, which indicates the willingness of small farmers to plant leguminous green manure. For small farmers who without planting confidence, although they also tend to choose leguminous green manure planting, their WTP for attribute variables is not strong.

In Model 2, the attribute coefficients of water quality, cultivated land quality and fertility, air quality, and days of natural disasters are all positive. They are significant at levels of 1, 1, 10 and 5%, respectively. Although the attribute coefficients in Model 4 are also positive, they are significantly different from Model 2 in terms of significance. Only days of natural disaster is significant at the 10% level. This result indicates that compared with those who have no confidence, confident small farmers prefer to improve environmental attributes that can be brought about by intercropping leguminous green manure. It can significantly enhance their WTP. From the payment amount perspective, the estimated result coefficients of the two models are both

Table 5. Results of the multinomial logit models.[1,2]

Variables	Have confidence		Without confidence	
	Model 1 coefficient (S.E.)	Model 2 coefficient (S.E.)	Model 3 coefficient (S.E.)	Model 4 coefficient (S.E.)
ASC	0.430 (0.272)	-2.148*** (0.559)	-1.588*** (0.438)	-3.675*** (1.091)
Water quality	0.336*** (0.111)	0.351*** (0.113)	0.332 (0.232)	0.303 (0.238)
Cultivated land quality and fertility	0.350*** (0.086)	0.374*** (0.089)	0.263 (0.225)	0.221 (0.230)
Air quality	0.203* (0.120)	0.217* (0.122)	0.258 (0.247)	0.216 (0.250)
Days of natural disaster	0.306** (0.156)	0.316** (0.159)	0.654* (0.358)	0.625* (0.362)
Payment amount	-0.011*** (0.004)	-0.012*** (0.004)	-0.018** (0.008)	-0.017** (0.008)
ASC*Gender		0.483*** (0.157)		-0.230 (0.291)
ASC*Age		-0.137* (0.076)		0.090 (0.139)
ASC*Risk preference		0.029 (0.093)		0.386** (0.173)
ASC*Education level		0.449*** (0.102)		0.423** (0.208)
ASC*Total annual income		0.105 (0.073)		-0.048 (0.149)
ASC*Part-time degree		0.290*** (0.077)		0.246* (0.127)
ASC*Related technical training		-0.029 (0.177)		-0.825* (0.454)
ASC*Environmental change perception		0.463*** (0.131)		0.145 (0.243)
Log likelihood	-1,704.864	-1,667.137	-563.627	-543.242
χ^2	24.60***	94.97***	13.14**	50.63***

[1] ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

[2] ASC = alternative specific constant; S.E. = standard error.

significantly negative at the level of 1%. This result indicates that as the amount increases, small farmer's willingness to plant leguminous green manure decreases, which is in line with realistic logic.

It can be seen from the interaction of ASC, and the socio-economic characteristics of small farmers, confidence, gender, age, education level, and part-time degree are the main factors affecting their WTP for the environmental attributes. The interaction coefficient of ASC and gender is significantly positive at the 1% level. This result indicates that compared with women, men are more inclined to plant leguminous green manure and have a higher WTP. The possible explanation is that men are more adventurous and accept new things. The interaction coefficient of ASC and age is significantly negative at the 10% level, indicating that with the aging of the agricultural labor force, their acceptance of leguminous green manure planting is gradually decreasing, similar to the research conclusion of Yang (2018). The interaction coefficient of ASC and education level is significantly positive at the 1% statistical level, indicating that small farmers with higher education levels are more inclined to participate in leguminous green manure planting. The possible explanation is that small farmers with relatively higher educational levels have a clearer understanding of the benefits of green manure. They have a stronger ability to master relative techniques. The interaction coefficient of ASC and part-time degree is significantly positive at the 1% level. The results show that the larger the proportion of agricultural income in the total household income, the higher their willingness to participate in leguminous green manure planting and the stronger WTP. The possible explanation is that small farmers, whose main source of income is agriculture, pay more attention to long-term interests and are more inclined to enhance agricultural sustainability by leguminous green manure. From the estimated results in Model 4, it can be seen that the WTP of small farmers without planting confidence is mainly affected by three factors: risk preference, education level, part-time degree. The interaction coefficient of ASC and risk preference is significantly positive at the level of 5%. This result indicates that small farmers with risk preference are more likely to accept new technology and change the existing planting mode in the case of no planting confidence. Similar to the estimation result of Model 2, the interaction coefficients of ASC, education level, and part-time degree are significantly positive, but its significance levels are slightly lower. This result indicates that compared with small farmers who have planting confidence, the education level, and part-time degree have a relatively weak positive effect on households without planting confidence.

From the estimated results in Table 5, the interaction coefficients of ASC and environmental change perceptions are significantly positive at the 1% level in Model 2, indicating that small farmers who perceive environmental degradation have a higher WTP for leguminous green manure environmental attributes than others. The possible explanation is that, as rural residents, the rural environment's quality directly affects daily life and economic income of small farmers. Therefore, small farmers who perceive environmental degradation are more likely to accept the green production method. In Model 4, the interaction coefficient of ASC and technical training is significantly negative at the level of 10%. This result indicates that relevant technical training fails to achieve the desired effect and reduces the willingness of small farmers without planting confidence to pay for environmental attributes of leguminous green manure. This result may be caused by the poor professional quality of the agricultural technology extension team, poor guarantees, and the weak acceptance of farmers themselves. To a certain extent, these factors have increased agricultural technology extension's difficulty, leading it difficult to achieve the desired goal.

4.3 WTP for environmental attributes

Table 6 depicts the marginal WTP of different small farmers to pay for leguminous green manure environmental attributes. The results in Model 2 indicate that small farmers with planting confidence have a positive WTP for all attributes. According to the attribute order in Table 6, they are 31.93 yuan/mu, 29.98 yuan/mu, 27.00 yuan/mu, 18.54 yuan/mu each year. The implicit prices can also be used to identify which attribute is more important to the respondents, which policymakers can use to assign more resources in favor of the attributes that have more implicit prices. The results show that cultivated land quality and fertility are the most important for small farmers, followed by water quality, days of natural disaster, and air quality. This order of importance is roughly the same as the existing knowledge.

However, the results in Model 4 show that small farmers without planting confidence only have a positive WTP for the attribute of natural disaster days. This result is very different from Model 2. The possible reason for this phenomenon is that compared with other environmental attributes, natural disasters directly affect the income of small farmers, so they are more sensitive to the environmental attribute of natural disasters.

From Table 6, the results show that small farmers with planting confidence have much higher willingness to pay for the environmental attributes of leguminous green manure than those without planting confidence. In addition, we also find that the WTP of small farmers with planting confidence is almost the same to the actual planting cost of leguminous green manure (117 yuan / mu) shown in Table 1, which indicates that planting confidence is the key factor to promote small farmers to plant leguminous green manure.

Table 6. Marginal willingness to pay for environmental attributes.

Attributes	Model 2	Model 4
Water quality	29.98	–
Cultivated land quality and fertility	31.93	–
Air quality	18.57	–
Days of natural disaster	27.00	36.42
Total	107.48	36.42

4.4 Robustness test

The CE results show small farmer's payment preferences for leguminous green manure environmental attributes and the sources of heterogeneity under the difference in planting confidence. However, due to small farmer's cognition and experimental design limitations, selection bias may occur. To ensure the reliability of the results, we use two methods: propensity score matching (PSM) and partial sampling (PS) to test the robustness of the above results.

■ *Propensity score matching method*

The PSM can reduce and correct possible selective biases by constructing a counterfactual analysis framework (Chen *et al.*, 2019). In this part, we compare the WTP for the environmental attributes of leguminous green manure of small farmers in the PSM and the CE to test whether the CE results are robust. First, under the framework of counterfactual analysis, this paper divides small farmers into the treatment and control groups based on whether they have confidence in leguminous green manure planting. We use 'payment amount' as the target variable, whether they have confidence in leguminous green manure planting as the processing variable, and socio-economic characteristics, technology, and environmental change perception as the matching variable. The independent sample t test is used to compare and analyze the differences in each index's mean values in the treatment group and the control group. The results are shown in Table 7.

Table 7 shows that the average amount paid by small farmers in the treatment group is much higher than the control group. In terms of matching variables, age, risk preference, education level, total annual income, and part-time degree also show a relatively high level. Before using PSM, it is necessary to examine the common support domain and balancing property to ensure matching quality. Figure 4 shows the kernel density plots before and after matching. It can be seen from the results of the figures that the proportion of sample loss in the matching process is small, and the common support domain is further expanded after matching. The matching effect is good.

The tests for the balancing property (Table 8) show that the mean standardized bias have been significantly reduced after matching for all the four (nearest neighbor, radius, kernel and Mahalanobis) algorithms. The Pseudo R^2, LR, P-value of the likelihood ratio tests also show the desired change, implying a good Matching quality. The PSM effectively reduces the difference between the treatment and control groups, and the explanatory variables are well balanced after matching. In summary, the sample matching quality is better.

Table 7. Tests for differences in the sample group.[1]

Variables	Treatment group		Control group		Mean differences
	Mean	Std. Dev[2]	Mean	Std. Dev	
Payment amount	108.304	63.496	32.639	57.791	-75.665***
Gender	0.636	0.481	0.597	0.491	-0.039
Age	47.055	10.361	48.583	10.865	1.528**
Risk preference	1.834	0.821	1.656	0.778	-0.178***
Education level	7.887	2.350	7.292	2.017	-0.595***
Total annual income	5.071	3.036	4.694	3.026	-0.376***
Part-time degree	2.233	1.005	2.392	1.097	0.159**
Related technical training	0.230	0.421	0.192	0.394	-0.038
Environmental change perception	2.271	0.578	2.222	0.579	-0.049

[1] *** and ** denote significance at the 1 and 5% levels, respectively.

[2] Std. Dev = standard deviation.

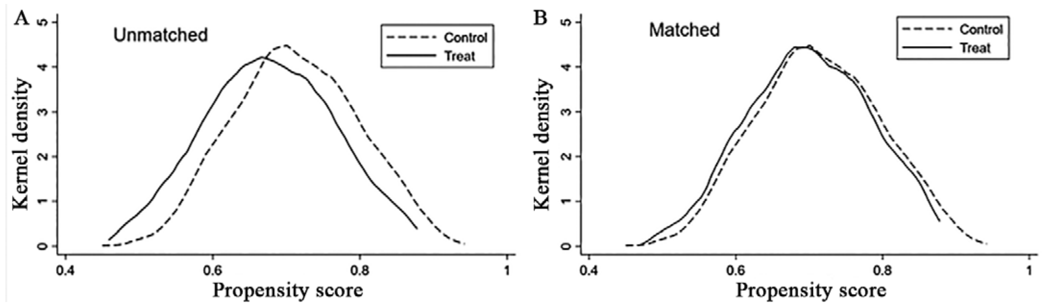

Figure 4. Propensity score before and after matching.

Table 8. Balancing property.

Matching method	Pseudo R^2	LR	*P*-value of LR	Mean standardized bias	Median bias
Before matching	0.030	44.08	0.000	15.8	14.7
Nearest-neighbor matching	0.004	9.76	0.282	4.8	4.8
Radius matching	0.021	19.82	0.011	13.3	13.3
Kernel matching	0.001	2.98	0.935	2.3	2.0
Mahalanobis matching	0.004	8.53	0.383	3.3	0.8

After the common support domain and balancing property have passed the test, we use the four (nearest neighbor, radius, kernel, and Mahalanobis) algorithms to measure the average treatment effect on the treated (ATT) of small farmer's leguminous green manure planting confidence on their WTP for environmental attributes.

First, we note from Table 9 that the ATT of the four matching algorithms are all positively significant at the level of 1%. This result indicates that the planting confidence can significantly enhance the small farmer's WTP, which is in line with the CE result. Second, in the treatment group and the control group, the average value of the payment amount is similar to the result calculated in Table 6. Based on this, it can be concluded that the above-mentioned CE results are robust.

■ *Partial sampling*

In this part, we test the robustness of the CE results by excluding sample farmers with high annual total income and a low proportion of agricultural income. The main reason is: For small farmers with high part-time income, agricultural income has a meager impact on their willingness to participate in leguminous green manure planting and the total family income so that they may have certain deviations in the choice of experimental programs.

Table 9. Average treatment effect on the treated (ATT) of small farmer's willingness to pay.

Matching method	Treatment group	Control group	ATT	*t*-stat
Nearest-neighbor matching	107.692	33.340	74.352	15.30
Radius matching	107.692	32.821	74.871	32.58
Kernel matching	107.692	34.241	73.451	18.75
Mahalanobis matching	107.692	34.675	73.017	15.14
Average	107.692	33.769	73.923	20.44

The specific measures are as follows: excluding the samples whose total annual income is more than 70,000 yuan and the proportion of agricultural income is less than 10%. In the end, we exclude 38 observations in total, of which 21 are excluded in the confident group, and the rest are from the without confidence group. The same regression method as the model in Table 5 is used for modeling. Table 10 shows that the regression results after sample adjustment have a high degree of consistency with the model in Table 5, so the model estimation results in this paper are robust.

■ *Provincial heterogeneity test*

In order to test whether the preference for environmental attributes and WTP of small farmers for leguminous green manure have provincial heterogeneity, we introduced province dummy variables in Model 9 and Model 11. The robustness test is carried out according to the method in section 4.4.2, and the results are shown in Model 10 and Model 12. Prior to this, we conducted an analysis of variance on the payment amounts of small farmers in different provinces to test whether there are differences. The results show that there are significant differences in the amount that confident small farmers are willing to pay in different provinces. The specific analysis of variance results is in the Supplementary Material (Table S1, Table S2).

The results of the interaction coefficients of ASC and province dummy variables in model 9 show that among different provinces, the small farmers in Hebei and Shandong are more willing to plant leguminous green manure, and they have a higher WTP. While for the small farmers without confidence, the difference between provinces does not affect their WTP. After excluding some samples, the results of Model 10 and Model 12 are still basically the same as those of Model 9 and Model 11, so the model estimation results are robust.

Table 10. Results of the multinomial logit models.[1,2]

Variables	Have confidence		Without confidence	
	Model 5 coefficient (S.E)	**Model 6 coefficient (S.E)**	**Model 7 coefficient (S.E)**	**Model 8 coefficient (S.E)**
ASC	0.439 (0.276)	-2.010*** (0.569)	-1.666*** (0.458)	-3.536*** (1.134)
Water quality	0.336*** (0.112)	0.351*** (0.115)	0.322 (0.242)	0.281 (0.247)
Cultivated land quality and fertility	0.353*** (0.087)	0.376*** (0.090)	0.281 (0.232)	0.231 (0.238)
Air quality	0.208* (0.122)	0.222* (0.1242)	0.263 (0.259)	0.211 (0.263)
Days of natural disaster	0.309* (0.159)	0.318** (0.162)	0.729* (0.387)	0.692* (0.389)
Payment amount	-0.011*** (0.004)	-0.012*** (0.004)	-0.019** (0.009)	-0.017** (0.009)
ASC*Gender		0.496*** (0.159)		-0.283 (0.298)
ASC*Age		-0.136* (0.078)		0.078 (0.144)
ASC*Risk preference		0.010 (0.094)		0.409** (0.178)
ASC*Education level		0.449*** (0.103)		0.388* (0.216)
ASC*Total annual income		0.132* (0.081)		-0.173 (0.180)
ASC*Part-time degree		0.267*** (0.079)		0.285** (0.133)
ASC*Related technical training		0.031 (0.180)		-0.782* (0.456)
ASC*Environmental change perception		0.447*** (0.134)		0.112 (0.249)
Log likelihood	-1,661.589	-1,624.431	-531.089	-512.658
χ^2	24.08***	93.45***	12.54**	46.57***

[1] ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

[2] ASC = alternative specific constant; S.E. = standard error.

Table 11. Results of the multinomial logit models in different provinces.[1]

Variables	Have confidence		Without confidence	
	Model 9 coefficient (S.E.)	**Model 10 coefficient (S.E.)**	**Model 11 coefficient (S.E.)**	**Model 12 coefficient (S.E.)**
ASC	-2.545*** (0.574)	-2.494*** (0.585)	-3.809*** (1.151)	-3.720*** (1.228)
Water quality	0.234* (0.122)	0.242** (0.123)	0.319 (0.243)	0.306 (0.252)
Cultivated land quality and fertility	0.279*** (0.096)	0.287*** (0.097)	0.230 (0.235)	0.251 (0.243)
Air quality	0.105 (0.128)	0.125 (0.131)	0.210 (0.254)	0.214 (0.267)
Days of natural disaster	0.210 (0.166)	0.232 (0.169)	0.614* (0.363)	0.689* (0.392)
Payment amount	-0.009** (0.004)	-0.009** (0.004)	-0.017** (0.008)	-0.018** (0.009)
ASC*Gender	0.359** (0.162)	0.372** (0.164)	-0.326 (0.306)	-0.362 (0.314)
ASC*Age	-0.152* (0.078)	-0.150* (0.079)	0.092 (0.141)	0.090 (0.145)
ASC*Risk preference	0.043 (0.096)	0.023 (0.098)	0.385** (0.175)	0.414** (0.181)
ASC*Education level	0.302*** (0.107)	0.304*** (0.108)	0.408* (0.212)	0.346 (0.220)
ASC*Total annual income	0.175** (0.076)	0.185** (0.083)	-0.042 (0.151)	-0.183 (0.182)
ASC*Part-time degree	0.328*** (0.083)	0.310*** (0.084)	0.248* (0.131)	0.299** (0.136)
ASC*Related technical training	-0.019 (0.184)	0.037 (0.187)	-0.820* (0.462)	-0.809* (0.465)
ASC*Environmental change perception	0.496*** (0.139)	0.476*** (0.142)	0.156 (0.254)	0.150 (0.262)
ASC*Hebei	0.538** (0.238)	0.533** (0.242)	0.193 (0.606)	0.257 (0.680)
ASC*Shandong	1.832*** (0.264)	1.817*** (0.267)	0.326 (0.650)	0.457 (0.718)
ASC*Anhui	0.080 (0.256)	0.122 (0.263)	0.031 (0.651)	-0.009 (0.725)
ASC*Jiangsu	0.277 (0.286)	0.242 (0.292)	0.135 (0.702)	-0.034 (0.776)
Log likelihood	-1,623.140	-1,580.435	--541.363	-509.838
χ^2	169.82***	168.67***	54.27***	51.78***

[1] ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

[2] ASC = alternative specific constant; S.E. = standard error.

5. Conclusions

This article studies the payment preference and influencing factors of small farmers for the leguminous green manure environmental attributes under the different planting confidence. We use a quantitative approach based on a CE to measure the specific amount that small farmers are willing to pay for the environmental attributes of leguminous green manure and the relative weight of various factors that influence farmer's decisions. The data comes from 5 major wheat-producing provinces in China: Henan, Shandong, Anhui, Hebei, and Jiangsu. The existing literature pays little attention to this topic, and the research can effectively fill it.

Our findings show that compared with small farmers without planting confidence, small farmers with planting confidence have a better marginal WTP for leguminous green manure environmental attributes, followed by cultivated land quality and fertility 31.93 yuan/mu/year, water quality 29.98 yuan/mu/year, and natural disaster days 27.00 yuan/mu/year, air quality 18.57 yuan/mu/year, and the total willingness to pay for environmental attributes is 107.48 yuan/mu/year. Besides, the factors affecting the two types of small farmers are also different. For small farmers who are confident in planting, gender, education level, part-time degree, and perception of environmental changes positively affect their WTP for leguminous green manure environmental attributes. Age negatively affects on their WTP. At the same time, small farmers without planting confidence are mainly affected by factors such as risk preference, education level, part-time degree, and technical training.

These findings lead to policy implications to improve small farmer's confidence in leguminous green manure planting. First, broaden the sources of information for small farmers. Establishing relevant public social platforms to promote information dissemination on green production technologies such as leguminous green manures and related environmental changes and improve the convenience of small farmer's access to information and resources. In this way, gradually change small farmer's production concept, promote the reduction of fertilizers and leguminous green manure planting. Second, improve small farmer's education level. From the results, we can see that education level has a significant positive impact on whether small farmers participate in leguminous green manure planting. Therefore, government departments should increase education investment in rural areas and help small farmers master new knowledge and technologies. Third, strengthen technological innovation. By improving the practical application effect of leguminous green manure planting, dispel small farmer's real worries.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2020.0190

Table S1. Homogeneity test of variance.
Table S2. Analysis of variance results.
Table S3. Tests for differences in the sample group of Henan Province.
Table S4. Tests for differences in the sample group of Hebei Province.
Table S5. Tests for differences in the sample group of Shandong Province.
Table S6. Tests for differences in the sample group of Anhui Province.
Table S7. Tests for differences in the sample group of Jiangsu Province.

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Conflict of interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and /or publication of this article.

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