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Incentive mechanism to promote corn stalk return sustainably in Henan, China

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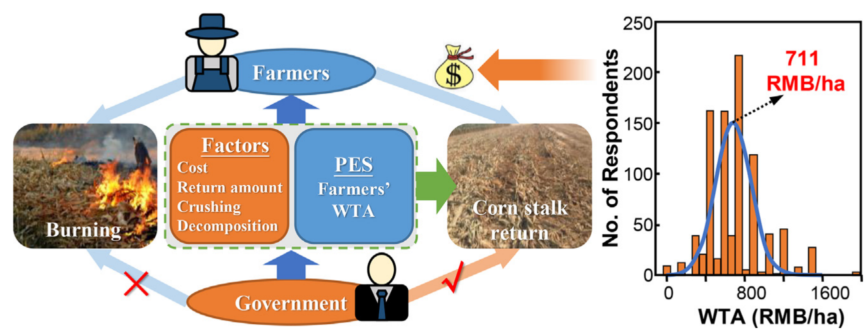
HIGHLIGHTS

- Corn stalk return (CSR) declines farmers' willingness to participate with the extra production cost.
- 45% of surveyed farmers are passive in CSR.
- Farmers' willingness to accept (WTA) compensation for CSR is 711 RMB/ha.
- Low machinery cost and rapid decomposition in CSR contribute to high participation and low WTA.

GRAPHICAL ABSTRACT



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ABSTRACT

Corn stalk return (CSR) can manage agricultural residues on the spot to avoid field open burning and protect the environment. However, the implementation of this measure encounters reluctance from farmers which hinders its sustainability. This study combined the economic (cost) and technical (return amount, crushing quality, and decomposition of corn stalk) aspects to examine the factors affecting farmers' willingness to participate in the CSR by using a logistic regression model. The level of willingness to accept (WTA) compensation and its determinants were analyzed by using a tobit model. Based on the survey of 925 farmers, this study found the likelihood of farmers' participation in CSR will be decreased when CSR has high machinery cost, an excessive amount of stalk, poor quality of crushing, and slow decomposing rate. The farmers' WTA for CSR was estimated at about 711 Chinese Yuan (RMB) per ha annually, much higher than the current compensation level of 75–225 RMB per ha in Henan. Farmers were willing to be compensated more because of the high cost and slow decomposing rate. The issues in economic and technical sides should attract more attention, and the compensation should be increased and the technical problems should be solved to stimulate farmers' willingness of CSR. By providing a fuller understanding of farmers' CSR behavior, this study can serve as a reference for the Chinese government to develop and implement better policies.

1. Introduction

Crop straw burning significantly contributes to daily and annual PM_{10} in urban areas and results in negatively affecting urban air quality in China (Liu et al., 2020). In recent years, actions of direct crop straw return are

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increasingly being encouraged by Chinese governments to hold back atmospheric pollution caused by straw burning, and achieve essential environmental purposes. In Europe, although a part of crop straws can be removed and used to produce bio-based materials and energy, a significant portion must be left in the field to preserve the soil structure and fertility and to maintain ecosystem services. About 57% of China's total straw has been returned to soil (China's People's Daily, 2017), and this number has been gradually increased in recent years. Currently, a growing number of studies are confirming the effects of crop straw return on yield production and soil quality. The existing academic researches in the field of crop straw return, however, tend to neglect the willingness of farmers' participation and stays deficiency in analyzing the possible influencing factors concerning the farmers' willingness to participate[1] in crop straw return. Scholars have shown that the farmers' willingness to participate has a marked impact on the sustainability of reusing agricultural waste (Atinkut et al., 2020). Crop straw return cannot carry out smoothly if farmers are unwilling to do it.

Farmers in the developed countries would like to keep part of straws in the soil proactively, for they know the advantages of crop straw return. However, there are differences in crop straw return between China and developed countries, like the amount and the frequency of returning. Due to the huge demand for food, China belongs to a highly intensive agricultural region (Li et al., 2017), and crop straws are required to be cleaned in a short time to prepare the land for the next crop. China's straw return actually refers to returning the full amount of straw into the soil, and two straw returns must be done in a year under the rotation system. These lead to a series of problems involved in carrying out and maintaining actions of crop straw return. For example, corn stalk incorporation needs additional mechanical crushing and deep plough, which increased the production cost by an average of 1774 RMB[2]/ha (Yin et al., 2016). Moreover, farmers may encounter obstacles at the technical side. The difficulties in implementing corn stalk return (CSR) include such as poor quality of mechanical crushing, and slow decomposition of corn stalk. Excessive stalk in soil results in poor root-soil contact, affecting roots taking and crop surviving (Gabisa and Gheewala, 2018; Zhu et al., 2018). Farmers' willingness to participate largely depends on the balance between the advantages and disadvantages of crop straw return. All of these disadvantages mentioned above reduced farmers' enthusiasm of participation. On the other hand, in most provinces of China, the production costs of crop straw return are fully burdened by farmers which has caused great discontent among farmers. Many farmers who participate in crop straw return just passively adopt it under straw burning ban policy (Huang et al., 2019).

Another limitation associated with the emerging arguments focusing on crop straw return lies with the economic subsidies that encourage farmers' behavior of participation. One viewpoint shows that farmers are responsible for the cost of straw disposal instead of letting the government pay for subsidies, according to the environment policy of who polluted, who solves. The second standpoint holds that crop straw return can enhance the service of the agricultural ecosystem, improve the air quality and soil fertility. Much attention should be paid on economic incentives to inspire farmers' willingness of crop straw return from the perspective of ecological service function (Ma and Qin, 2009). The economic incentive for crop straw return is in line with the purpose of payments for environmental services (PES) in developed countries (Alix-Garcia et al., 2018) which aims to preserve or restore ecosystem services through financial incentives. PES has become an increasingly popular tool for environmental management, supplementing policy tools that were previously widely focused on command-and-control measures (Ezzine-de-Blas et al., 2016). Although some local governments (e.g., Henan, Heilongjiang) have been implementing PES policy by compensating some money to farmers for participation in crop straw return, the compensation level has been criticized by farmers for it is much lower than their willingness to accept compensation (WTA). It cannot effectively stimulate farmers to participate in crop straw return voluntarily (Ping et al., 2013). The farmers' WTA for participation in crop straw return can reflect the incentives they may require and the contributions they would be prepared to make as responsible citizens. Presently, the existing researches about estimating the PES based on WTA are rich, such as reducing agriculture non-point source pollution (Beharry-Borg et al., 2013), establishing a recreational woodland (Bateman, 1996), forest conservation (Lindhjem and Mitani, 2012) and habitat preservation (Amigues et al., 2002). However, this important theme has been rarely concerned with scholarships.

In response to the above two limitations, this study draws on views from Jan and Akram (2018) and extends it to the context of farmers' willingness of crop straw return. In a recent study, Jan and Akram showed that technical issues will influence rural residents' choice. The technical issues, such as return amount, decomposition rate, and crushing quality (Yang et al., 2015; Li et al., 2018; Zhang et al., 2018) have been questioned for the unfavorable outcomes to on crop straw return, and can together with the production cost become barriers of this project's development (Yin et al., 2016). Following their lead, we combine economic and technology perspectives to explore two important issues regarding farmers' willingness of participation: What are the factors impeding farmers to participate in crop straw return? And how much money should be appropriate to boost farmers' participation. Considering corn stalk production is the most among crop straws (Shi et al., 2017) and the open burning amount of corn stalk is also enormous (Hong et al., 2016), our study focus on farmers' willingness of CSR. Based on the survey data of 925 rural farmers, we have found that farmers are reluctant to return corn stalk to the field when the cost is high, return amount is excessive, crushing quality is poor and decomposing rate is slow but their willingness may be changed on considering the benefits of soil fertility improvement. The calculated farmers' expected compensation is far beyond the present compensation level.

This study extends research on farmers' willingness of CSR on two major dimensions. First, it is among the first attempts to develop relevant factors to discover the reason for whether farmers are willing to participate in CSR. Although some studies have focused on possible reasons influencing farmers' choice, most efforts to date have either discussed the effects of socio-economic characteristics (gender, education, family's income level) or considered policy instruments such as straw burning ban policy (Liu and Lu, 2013). This study provides an interesting insight into the possible determinants including the CSR's machinery cost and technical aspects to achieve a better understanding of what efforts can be made to change farmers' unwillingness. Second, in light of the importance of economic incentives, compensated perspective of farmers' willingness were build, in order to achieve a comprehensive understanding of the compensation making of PES policy on CSR. Study's results can provide a reference of CSR for the corn cultivation regions of the same latitude in the world.

The article is organized into four sections. We begin with methodology description. We then present survey findings. The third section analyzes the economic and technical factors associated with farmers' willingness to participate and accept, and discuss the expected subsidy amount. We conclude the article with a discussion about the contributions and limitations of the study. Given the objectives of the study, the following hypotheses were formulated:

H1. Farmers who think machinery cost for CSR is too high are more unwilling to participate in CSR and willing to accept more compensation.

H2. Farmers who think some difficulties still exist in the process of CSR, such as excessive corn stalk, poor quality of stalk crushing, and slow decomposing rate of stalk, tend to be more unwilling to participate in CSR and willing to accept more compensation.

[1] "Willingness to participate" refers to if respondents are willing to participate in this project, which is different to "Willingness to accept compensation (respondents' expected compensation for participating in this project)".

[2] 1 RMB = 0.15 USD (9 July 2019).

H3. Farmers who think CSR can be beneficial to atmosphere environment, soil fertility, or wheat growth, are more willing to participate in CSR and willing to accept less compensation.

H4. The cultivation area has a significant and positive effect on the participation of CSR and a negative effect on WTA.

H5. Corn stalk yield has an effect on farmers' participation of CSR and WTA.

H6. The socio-economic characteristics (e.g., age, gender, education, and income) of farmers have effects on the participation of CSR and WTA.

2. Methodology

2.1. Study sites

Corn cropping regions in China can be divided into six major zones, i.e. Northern spring corn district, Yellow-Huai River Valley summer corn district, Southern corn district, Southwest corn district, Northwest corn district, and Qinghai Tibet Plateau corn district (Fig. 1), in which Northern and Yellow-Huai River Valley districts are the main corn cropping areas. They produced 44.6% and 32.6% of the total corn production, respectively in 2016, China (Rural Socioeconomic Investigation Department, National Bureau of Statistics of China, 2017).

This study site was located in Henan province, which belongs to Yellow-Huai River Valley corn district under wheat-corn rotation system. Henan has 3.9 million hectares of corn crop (National Bureau of Statistics of China, 2018), nearly 10% of the national corn planting area. About 22 million tonnes of corn were produced. Along with it, a significant amount of corn stalk was produced. In 2015 corn harvesting season (October 1 to October 31), Henan was detected 92 spots of open field burning of corn stalk and had the most fire points in China. Atmospheric pollution occurred unavoidably, and PM_{10} level became much higher during this period than that before/after the harvest (Fig. 1). Hence, it is full of meanings to promote CSR in Henan province.

2.2. Survey structure and data collection

For collecting data on farmers' willingness, a face-to-face questionnaire was designed. The questionnaire was pre-tested from August 3 to 7, 2016. From the results of this pretesting survey, the questionnaire was refined to make sure comprehension and clarity. The final questionnaire was confirmed and consisted of the following five sections: (1) briefly describing the study part; (2) basic information about corn stalk disposal of respondents; (3) farmers' attitude to CSR; (4) farmers' willingness to accept compensation; and (5) socio-economic characteristics of respondents. Subsequently, large-scale field interviews were performed from September 19 to November 10, 2016. A stratified random sampling method followed by Ding et al. (1996) was used for selecting the farmers to be surveyed. Firstly, typical cities of Henan province were determined including Zhoukou and Shangqiu, Kaifeng and Xuchang, Luoyang, and Hebi. Secondly, in each city, two or three counties were randomly selected. Thirdly, in each county, two or three small towns were randomly chosen. Fourthly, five villages were randomly chosen from each town. Fifthly, in each village, families were selected associated with households in the list from village committees by systematic random sampling method. Finally, one household member who was randomly selected to interview. Moreover, the respondents in our survey are agricultural producers, most of whom can decide whether to adopt CSR.

2.3. Determination of sample size

In order to appraise the sample size, we followed Gonick et al. (1993) and Pituch et al. (2013). The calculation method of the sample size is as follows:

$$x = Z_c^2 r(100-r) \tag{1}$$

$$n = \frac{N}{\left((N-1)E^2 + x\right)} \tag{2}$$

$$E = \sqrt[2]{(N-n)/(n(N-1))} \tag{3}$$

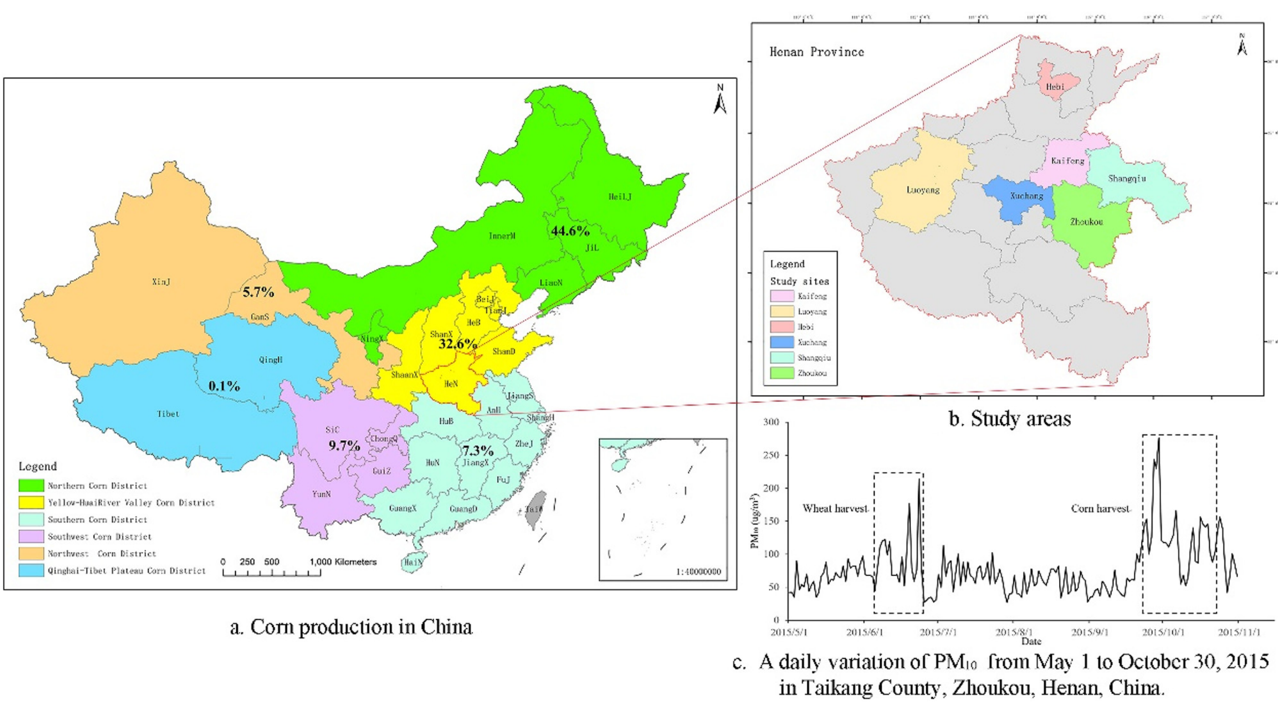

Fig. 1. Study sites description. (a) Corn production regions, (b) study areas, and (c) A daily variation of PM_{10} in 2015, Taikang, Zhoukou, Henan, China.

where x represents the margin of error, 5% is a common choice; Z_c is the critical value for the confidence level c, the typical choice is 95%; N is the rural population size of the study area; n is the number of sample size; E is the standard deviation. In 2016, the total rural population of our study area was 49 million, i.e. 5.3 million in Zhoukou, 4.4 million in Shangqiu, 3.1 million in Luoyang, 2.5 million in Kaifeng, 2.2 million in Xuchang, and 0.7 million in Hebi (Henan Provincial Bureau of Statistics, 2017). It can be estimated that the recommended size of the survey should be no less than 385. Generally, a lower margin of error and higher confidence level requires a larger sample size, and the larger the sample size, the more representative of the sample. In total, 931 farmer surveys were collected using the stratified random sampling method and 925 complete responses were effective, i.e., 220 questionnaires from Zhoukou, 258 from Shangqiu, 85 from Xuchang, 99 from Kaifeng, 103 from Luoyang, and 160 from Hebi.

2.4. Open-ended elicitation method

Several methods (e.g. open-ended questions, payment cards, iterative bidding games, and dichotomous choice questions) can elicit respondent's WTA (Hanemann et al., 1991; Herriges and Shogren, 1996; Heinzen and Bridges, 2008). Open-ended questions were used to collect survey data in this study. In an open-ended format of WTA elicitation, the respondents are directly asked what is the minimum amount of cash you are willing to accept. However, owing to respondents being unsure as to how they should value environmental goods, an open-ended question often befalls high rates of non-response and/or resulting in lots of zero as well as large values (Eberle and Hayden, 1991), then it may be abandoned. After pretesting the questionnaire questions by face to face interviews, we found that the non-response rate of the open format method in this survey was very low. Moreover, in China, crop straw return has been implemented for many years. Farmers are very familiar with CSR which is significant technology introduced suggested by the government. Many respondents can articulate the advantages and disadvantages of CSR, then tell an expected compensated value. This is supported by Mitchell and Carson (1986) that open-ended questions work well when respondents are familiar with the concept undervaluation. On the other hand, Amigues et al. (2002) are afraid that suggesting values would have been difficult. This is because that if the suggested values were perceived as being 'too low', farmers would be upset and suspect sincerity and attitude of the government. Suggesting large values might stimulate high WTA value or would make the study proposed not credible. Open-ended questions might be the best way to elicit respondents' maximum or minimum prices (Van den Berg et al., 2005). Based on these reasons, the open-ended method was used in which respondents were asked what is the minimum compensation per mu that one would have to receive in order to participate in returning corn stalk to the field.

2.5. Models and variables

A binary logistic model and a tobit model are used, respectively, to analyze determinants of farmers' willingness for CSR participation and compensation. The same explanatory variables were included in the two econometric models in order to conduct a combined analysis of their impacts on willingness for participation and compensation.

This logistic model was well applied for participation analysis (Kabir et al., 2013; Sheikh et al., 2003; Vanslembrouck et al., 2002) and employed to estimate the potential occurrence of a certain event by fitting data to a logistic distribution function (Morgan and Teachman, 1988). Logistic regression is a useful analysis method to explain the relationship between some independent variables and a binary dependent variable, expressed as a probability, that has only two possible values (such as willingness or unwillingness). The logistic regression model was specified as Eq. (1), where P is the probability that a farmer is willing to participate in CSR, β are the coefficients to be estimated, X are independent variables, and ε is the error term. The dependent variable is the willingness to participate in CSR and is binary (Yes is 1 and No is 0).

$$\ln[P/(1-P)] = \sum \beta X + \varepsilon \tag{4}$$

The tobit model was widely employed to explain bids amounts when the dependent variable is censored (left-, right-, or bi-censored) for a significant fraction of the observations, to escape biased and inconsistent parameter obtained by ordinary least squares regression. In the standard tobit model (Tobin, 1958), the dependent variable y is left-censored at zero:

$$y_i^* = X_i\beta + \varepsilon_i, \varepsilon_i \sim \mathrm{N}(0, \sigma^2) \tag{5}$$

$$y_i = \begin{cases} y_i^*, if\, y_i^* > 0 \\ 0, if\, y_i^* \le 0 \end{cases} \tag{6}$$

where for the ith individual, is the latent (unobservable) variable; y_i is observed; X_i is a vector of independent variables; β is an unknown parameter vector to be estimated; and ε_i is the error term assumed as normally distributed with mean zero and constant variance sigma square (σ^2). Then, the expected value of y is:

$$\begin{aligned} E(y_i) &= \Pr(y^* \le 0) \cdot E(y_i|y_i = 0) + \Pr(y^* > 0) \cdot E(y_i|y_i > 0) \\ &= X_i\beta F(X_i\beta/\sigma) + \sigma f(X_i\beta/\sigma) \end{aligned} \tag{7}$$

where F is the cumulative distribution function of a standard normal random variable, f is the normal density function, σ is the standard deviation. Moreover, in the generalization of the standard tobit model, the dependent variable can be censored on either or both sides and the lower and/or upper limit of the dependent variable can be any figure:

$$y_i^* = X_i\beta + \varepsilon_i, \varepsilon_i \sim \mathrm{N}(0, \sigma^2) \tag{8}$$

$$y_i = \begin{cases} a, if\, y_i^* \le a \\ y_i^*, if\, a < y_i^* < b \\ b, if\, y_i^* \ge b \end{cases} \tag{9}$$

where a is the lower limit and b is the upper limit of the dependent variable. In the analysis of the farmers' WTA for CSR, a is 0 and b is 1500. The expected value of the latent variable y_i^* in this model is

$$E(y_i^*) = \beta' X \; and \; \partial E(y^*)/\partial X_i = \beta_i \tag{10}$$

Followed Maddala (1983), the expected value of y in the interval between a and b is:

$$E(\mathrm{y}_i, a < y_i^* < b) = \beta X_i + \sigma[f(Z_a) - f(Z_b)]/[F(Z_b) - F(Z_a)] \tag{11}$$

where Z_a is $(a - \beta X_i)/\sigma$, Z_b is $(b - \beta X_i)/\sigma$.

When the dependent variable is at the lower limit a, the change in expected value of y is given by:

$$\partial F(Z_a)/\partial X_i = \beta/\sigma f(Z_a)$$

When the dependent variable in the interval between a and b, the change in expected value of y is given by:

$$\partial E(\mathrm{y}_i, a < y_i^* < b)/\partial X_i = \beta_i \left\{ 1 + \frac{Z_a f(Z_a) - Z_b f(Z_b)}{F(Z_b) - F(Z_a)} - \frac{[f(Z_a) - f(Z_b)]^2}{[F(Z_b) - F(Z_a)]^2} \right\} \tag{12}$$

When the dependent variable is at the upper limit b, the change in expected value of y is given by:

Table 1
Definition and descriptive statistics of explained variables and explanatory ones.

Variables	Definition and unit	Mean	Standard deviation
WTA	Farmers' WTA for participation in corn stalk return (RMB/ha)	710.92	286.74
PARTICIPATE	1 if farmer is willing to participate in corn stalk return	0.73	0.44
COST	1 if farmer thinks machinery cost is too high	0.74	0.44
AMOUNT	1 if farmer thinks it is not good to return full amount of corn stalk into the field	0.28	0.45
CRUSHING	1 if farmer thinks crushing quality of corn stalk is poor	0.33	0.47
DECOMPOSITION	1 if farmer thinks decomposing rate of corn stalk in the soil is slow	0.32	0.47
SOIL	1 if farmer thinks corn stalk return improves soil fertility	0.90	0.30
ATMOSPHERE	1 if farmer thinks stalk return protects the atmosphere environment	0.99	0.10
GROWTH	1 if farmer thinks corn stalk return is beneficial to wheat growth	0.48	0.5
AREA	Cultivation area of corn (ha)	0.45	0.31
YIELD	Yield of corn stalk (Kg/ha)	7462.33	2535.69
$YIELD^2$	Square of corn stalk yield		
AGE	Farmer's age	55.9	10.45
AGE^2	Square of age		
GENDER	Farmer's gender	0.7	0.46
EDUCATION	Education in years	7.65	2.66
INCOME	Per capita annual disposable income of rural household (RMB)	7093.26	9496.62
ZHOUKOU	(1:Zhoukou; 0: other cities)	0.24	0.43
SHANGQIU	(1:Shangqiu; 0: other cities)	0.09	0.29
XUCHANG	(1:Xuchang; 0: other cities)	0.28	0.45
KAIFENG	(1:Kaifeng; 0: other cities)	0.11	0.31
LUOYANG	(1:Luoyang; 0: other cities)	0.11	0.31
HEBI	(1:Hebi; 0: other cities)	0.17	0.38

$$\partial F(Z_b)/\partial X_i = \beta/\sigma f(Z_b) \tag{13}$$

Finally, robustness of the study results was conducted to check whether results are maintained by using a linear probability model (Paunov, 2016). Moreover, both the WTA calculated based on parameter estimation and the WTA, of non-parametric calculation were compared to test the robustness of the research results. The independent variables selected and included in the above two models are farmer's thought of CSR on machinery cost (*COST*), thought of difficulties in making CSR including stalk-returning amount (*AMOUNT*), quality of stalk crushing (*CRUSHING*), and decomposition of stalk (*DECOMPOSITION*), thought of CSR effects on soil fertility (*SOIL*), on atmosphere environment (*ATMOSPHERE*), and on wheat growth (*GROWTH*), cultivation area (*AREA*), corn stalk yield (*YIELD*), yield square ($YIELD^2$), farmer's age (*AGE*), age square (AGE^2), farmer's gender (*GENDER*), education in years (*EDUCATION*), household income (*INCOME*), region dummy variables (ZHOUKOU, HEBI, SHANGQIU, XUCHANG, LUOYANG). Definitions of the variables are presented in Table 1.

3. Results

3.1. Comparing cost of corn stalk managements

We calculated the cost from managing corn stalk to sowing wheat. Open burning of corn stalk was the cheapest (1350 RMB/ha) among the three treatments (Table 2). Generally, corn stalk was firstly crushed to a length of 8–10 cm and spread in the field. In order to make sure stalk shorter (about 5 cm) and eliminate corn stubble, the shredding step should be done one more time. The crushed stalk on the soil surface should be instantly inverted to the soil by deep ploughing to reduce the time of exposure to air, which can reduce the loss of stalk moisture and nutrients. Harrowing immediately after deep ploughing can break up clods and conserve soil moisture. CSR increased machinery cost by 1500 RMB/ha compared to open burning, due to the increased operations, i.e. twice crushing, ploughing stalk into the subsoil, and harrowing. Supposing the stalk storage station is 5 km away from the farmland, the production costs of collecting and selling corn stalk was 2895 RMB/ha when considering labour opportunity, fuel consumption and earning. Hence, either CSR or sale treatment, the cost of them is average 1500–1545 RMB/ha higher than open burning. What we have to pay attention to is that if farmers don't mind the opportunity cost of farmer labour for cutting stalk manually, the cost of collecting and selling corn stalk will be reduced by 1500 RMB/ha, then the cost will be similar to open burning of corn stalk. However, in reality, farmers will take this part into account. In addition, manual collecting and selling will take more time than open burning.

3.2. Farmers' willingness to participate in corn stalk return and its determinants

3.2.1. Responses of participation

Although 91% of total respondents had CSR behavior (Table 3), 24% of them expressed that they were actually unwilling to adopt CSR

Table 2
Total cost of corn stalk managements in Zhoukou, Henan, China, 2016.

Type	Costs (RMB/ha)								
	Corn stalk crushing	Manual cutting stalk[a]	Transporting (5 km)[b]	Earning[c]	Ploughing	Rotary tillage	Harrowing	Wheat sowing	Total
Open burning	/	/	/	/	/	900 (2x)	150 (x[d])	300	1350
Incorporation	900 (2x)	/	/	/	450 (x)	900 (2x)	300 (2x[e])	300	2850
Collecting for sale	/	1500	2445	2400	/	900 (2x)	150 (x)	300	2895

Data were obtained by visiting farmers who burned corn stalk, returned corn stalk to the field, and collected stalk for sale.
[a] Is the opportunity cost of farmer labour. It took 1500 RMB (about 150 h) for collecting corn stalk per hectare.
[b] Sources from Chen (2015).
[c] Calculated according to corn stalk sale price of 0.08 RMB/kg and 30,000 kg fresh corn stalk collected per hectare.
[d] Means that program runs once.
[e] Means that program runs twice.

Table 3
Statistics of the respondents' choices and the reasons for their unwillingness to participate.

Items	Options	Sample size	Proportion (%)
Did you return corn stalk to the field in 2015?	Yes	844	91
	No	81	9
Do you think crop straw returned to the field can protect the atmosphere?	Yes	916	99
	No	9	1
Do you think the government should make financial subsidy to farmers who returned corn stalk to the field?	Yes	909	98
	No	16	2
Are you willing to adopt corn stalk return for protecting the atmosphere?	Yes	675	73
	No	250	27
Reasons for not willing to participate			
1 Affect wheat sowing		97	39
2 High machinery cost		73	29
3 Affect seedling emergence of wheat		61	24
4 Others		19	8

(Table 4). The remained 76% of them were willing to adopt CSR. However, 28% of them answered that their willingness is owing to the pressure of burning ban policy (Table 4). This implies that approximately 45% of farmers who returned corn stalk to the field were indeed passive. Even though 99% of total respondents admitted crop straw return could protect the atmosphere, 98% of total respondents consider that the government should compensate them for CSR (Table 3). That means, although most of the surveyed farmers returned corn stalk to the field, only 2% of these farmers were willing to participate in CSR voluntarily without any compensation, which is consistent with Huang et al.'s (2019) survey results on farmers' willingness of compensation for wheat straw return.

3.2.2. Determinants of farmers' willingness to participate in corn stalk return

Stata version 12.0 (Stata Corporation, College Station, Texas USA) was used to analyze survey data. Estimation results of the logistic model for participation in CSR are presented in Table 5. In the participation model, the log likelihood did not vary at a value −432.69 after 6 iterations. The LR χ^2 value for the model was 214.15 and is significant at the 1% level, showing that the coefficients of the independent variables are not equal to zero. A total of 12 independent variables were considered in the model, out of which 9 variables, i.e. *COST*, *AMOUNT*, *CRUSHING*, *DECOMPOSITION*, *SOIL*, *YIELD*, *AGE*, AGE^2 and *GENDER* were found to significantly influence farmers' willingness to participate in CSR.

Farmers' willingness to participate was affected by these sides of CSR's cost and technical issues. In light of the survey, the increased machinery cost of CSR was 1500 RMB/ha (Table 2). The farmers thought the machinery cost for CSR was too high to be willing to participate, about 12.26% less probability of willingness to participate in CSR, suggesting that the high machinery costs caused by CSR hindered farmers' participation to a certain. The technical issues including *AMOUNT*,

Table 4
Reasons for willingness of 844 farmers who returned corn stalk to the field.

Participate	Reasons	Frequency	Ratio (%)
Unwillingness	1 Affect wheat sowing	83	42
	2 High machinery cost	54	27
	3 Affect seedling emergence of wheat	53	27
	4 Others	9	5
	Total	199	24
Willingness	1 To improve soil fertility	379	59
	2 The burning ban policy	181	28
	3 Cost-saving in fertilizer input	61	9
	4 Others	24	4
	Total	645	76

Table 5
Regression results for farmers' willingness to participate.

Variables	Coefficients	z-Value	Average marginal effects
COST	−0.8139***	−3.57	−0.12264
AMOUNT	−1.6119***	−8.24	−0.24288
CRUSHING	−0.4572**	−2.43	−0.06889
DECOMPOSITION	−0.3811**	−2.02	−0.05742
SOIL	0.7510***	2.89	0.11317
ATMOSPHERE	1.0043	1.27	0.15133
GROWTH	0.1633	0.8	0.02461
AREA	0.3601	1.2	0.05427
YIELD	0.0002*	1.92	0.00002
$YIELD^2$	−1.45E-09	−0.36	−2.19E-10
AGE	0.1130**	1.90	0.01703
AGE^2	−0.0011**	−1.93	−0.00016
GENDER	−0.3593*	−1.75	−0.05414
EDUCATION	−0.0104	−0.29	−0.00156
INCOME 1000	−0.0030	−0.35	−0.00045
ZHOUKOU	0.2459	0.76	0.03706
HEBI	−0.2674	−0.77	−0.04029
SHANGQIU	0.0598	0.15	0.00901
XUCHANG	−0.2207	−0.7	−0.03325
LUOYANG	0.2341	0.62	0.03527
Constant	−2.9436	−1.56	
Log likelihood	−432.6858		
LR χ2 (20)	214.15***		
Pseudo R2	0.1984		
Sample size	925		

***, ** and * show significance levels at 1%, 5% and 10%, respectively.

CRUSHING, and *DECOMPOSITION* had a significant negative influence on the behavior toward CSR. Farmers who thought that it was not proper to return the full amount of corn stalk into the soil were less inclined to do it. This *YIELD* variable shows that with the increase of stalk output, the likelihood of farmers' CSR raises, but the negative coefficient of $YIELD^2$ indicates that when the output becomes to a certain value, the probability of farmers' CSR decreases. This is consistent with the decline in farmers' willingness to participate due to excessive return amount. Combined with *AMOUNT*, *CRUSHING*, *DECOMPOSITION*, the probability of a farmer's willingness of CSR would be decreased by 36.91% due to the problems of the three variables. On the other side, CSR improves soil fertility. In this survey, 59% of farmers who returned stalk to the field reported that CSR could increase soil fertility. Farmers who perceived CSR that could improve soil fertility were more willing to participate. Interestingly, *GENDER* had a negative effect on farmers' willingness to participate in CSR. It means that female respondents expressed greater possibility to adopt CSR than males. It may be because collecting corn stalk by female farmers is difficult due to their weak labor ability.

3.3. Farmers' WTA for participating in corn stalk return and its determinants

3.3.1. Farmers' WTA for participating in corn stalk return

Considering the Tobit model, the expected WTA for participating in CSR was 711.21 RMB/ha (Table 6), accounting for approximately 47% of the increased production cost (1500 RMB/ha) caused by CSR compared to open burning of corn stalk. Moreover, most farmers expected the compensated values for CSR falling in the range of 600–800 RMB/ha (Fig. 2). In reality, either there is no compensation or the compensation rate for CSR was minimal in Henan, just about 75–225 RMB/ha annually, much lower than farmers' WTA, and cannot effectively encourage farmers to participate in CSR. According to farmers' WTA and the sown area of Henan province, the evaluated total governmental financial compensation for CSR was about 2.8 billion RMB.

Table 6
Mean WTA versus actual government subsidy.

Description	Sample mean WTA (RMB ha^{-1} $year^{-1}$)	Actual subsidy (RMB ha^{-1} $year^{-1}$)	Sown area[a] (ha)	Aggregate value (RMB)
Sample mean	710.92	0, 75–225	3,999,000	2,842,969,080
Expected WTA	711.21	0, 75–225	3,999,000	2,844,128,790

[a] Data are from China Statistical Yearbook 2018 (National Bureau of Statistics of China, 2018).

3.3.2. Determinants of farmers' WTA

Estimation results of the tobit model for farmers' WTA are presented in Table 7. Based on the regression results, Farmers' WTA was also affected by costs and technical sides of CSR. *COST* had a significant positive impact on farmers' WTA. The surveyed farmers who thought the machinery cost was too high tended to be willing to accept a higher subsidy. The marginal effect result showed that these respondents were willing to accept 157.48 RMB/ha more than those who did not think machinery cost high. *DECOMPOSITION* as a technical issue was also found to positively influence farmers' WTA for CSR. Farmers who thought the decomposition of corn stalk in soil was too slow might increase WTA by 62.83 RMB/ha. On the other hand, farmers who thought CSR could increase soil fertility were willing to accept a lower compensation. *AREA* also significantly decreased farmers' WTA amount. This may because large areas led to a decrease in total costs of per unit area for CSR. *AGE* had a negative and significant effect on farmers' WTA amount, while Age^2 was opposite. This suggests that expected WTA of farmers' CSR raises with age, but when they reach a certain age, their expectations will drop. *EDUCATION* was negatively correlated with WTA amount. Farmers' WTA decreased with increasing education of the farmers. This may because that education is likely to ensure a better understanding of the benefits linked to CSR, especially atmosphere protection by CSR (Appendix Table A). *INCOME* showed that the wealthier farmers, as expected, are more likely to accept less compensation for CSR. It should also be noted that education level and income level are related, that is why *EDUCATION* and *INCOME* often display the same tendency.

Results for robustness test by using a linear probability model was shown in Appendix Table B. The findings are robust when using the linear probability model, which also shows that *COST*, *AMOUNT*, *CRUSHING*, and *DECOMPOSITION* significantly reduced possibility of CSR, while farmers were willing to participate in CSR for improvement of soil fertility. Regression results of linear probability model for farmers' willingness of accept was also consistent with the previous tobit model. Farmers' WTA value was maintained by parameter estimation and non-parametric calculation.

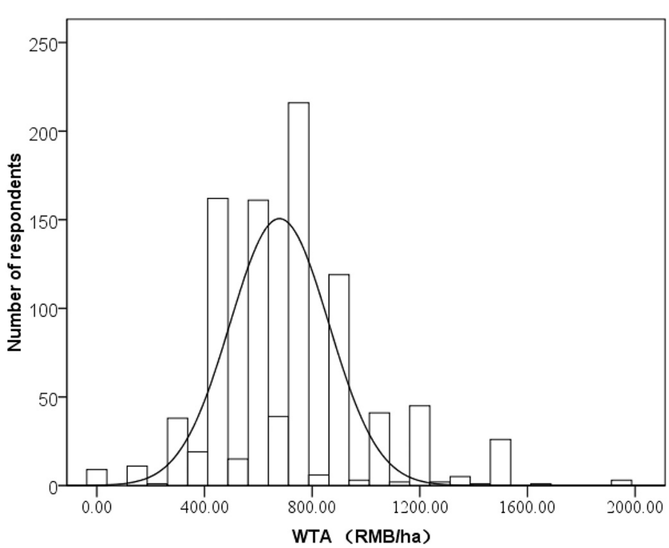

Fig. 2. The histogram of farmers' expected WTA.

4. Discussion

In this study, we explore what kind of possible aspects could influence the farmers' choice with CSR. We assume that economic issues such as the cost of CSR are high, and technical issues such as CSR technology has a few shortcomings. The two limitations mentioned above may be the main factor restricting farmers to return corn stalk to the field. If the hypothesis is confirmed, the government could be suggested to focus on solving existing problems of CSR while establishing policies related to promoting farmers to participate in CSR. Only solved these problems, CSR can be in line with farmers' appeal, generate corresponding benefits, finally be feasible for sustainable development.

For the analysis of farmers' willingness to participate, we found that as assumed, the cost factor of economy is one of the considerable factors which reduces the likelihood of farmers' participation in CSR. According to the results of calculating the cost of corn stalk managements, CSR increases machinery cost of 1500 RMB/ha, which accounts for approximately 9% of the total corn production cost (The Price Division of the National Development and Reform Commission, 2017). In addition, considering the farmers' average land size is 0.447 ha, which means 670 RMB of family expenditure has to be increased, also accounting for about 9% of the annual household income (7093 RMB). In total, farmers are forced to cost a lot due to adopting CSR and fully burden the increased cost. Hence expenditure may stop farmers to participate in CSR and can also explain why there are 98% of the surveyed farmers believe the government should compensate them for CSR.

Follow the possible compensation issue, then we then analyzed the farmers' expected WTA value. The surveyed farmers' willingness to be compensated amount was 711 RMB/ha, which is 47% of the increased

Table 7
Regression results for farmers' willingness to accept compensation.

Variables	Coefficients	t-Value	Marginal effects
COST	157.487***	7.64	157.4872
AMOUNT	25.408	1.14	25.40803
CRUSHING	9.874	0.48	9.873977
DECOMPOSITION	62.826***	3.05	62.82551
SOIL	−56.477*	−1.91	−56.4766
ATMOSPHERE	−22.779	−0.26	−22.77895
GROWTH	−46.515	−2.27	−46.51483
AREA	−41.202**	−1.41	−41.20223
YIELD	−0.017**	−2.43	−0.02
$YIELD^2$	1.70E-07	1.41	1.70E-07
AGE	−3.312*	−0.51	−3.31
AGE^2	0.019*	0.31	0.02
GENDER	31.334	1.52	31.33
EDUCATION	−10.655***	−2.97	−10.66
INCOME 1000	−2.217**	−2.36	−2.22
ZHOUKOU	88.769***	2.75	88.77
HEBI	−87.94**	−2.53	−87.94
SHANGQIU	−41.657	−1.07	−41.66
XUCHANG	12.645	0.4	12.64
LUOYANG	42.376	1.14	42.38
Constant	983.352***	4.79	
Log likelihood	−6248.169		
LR $\chi 2$ (20)	203.11***		
Pseudo R2	0.0160		
Sample size	925		
Uncensored observations	886		

***, ** and * show significance levels at 1%, 5% and 10%, respectively.

machinery cost for CSR. It indicates that farmers are willing to bear 53% of the increased cost by themselves. Put another way that farmers think both themselves and the government should pay half of the responsibility for environmental protection by CSR. Previous studies have investigated the effects of CSR on soil carbon dynamics (Hooker et al., 2005), crop yield and soil organic matter (Wang et al., 2015); however, lack of analysis in the literature from the perspective of farmers' WTA compensation for CSR. The first survey on farmers' WTA for wheat straw return was carried by Huang et al. (2019), showed that the average WTA of the surveyed farmers for adopting wheat straw return was 479 RMB/ha. The various WTA values between CSR and wheat straw return may cause by survey sites with various income levels and the differences in the increased production cost. The higher increased CSR cost leads to a relatively higher WTA value. The total value of farmers' WTA estimated in our research was found to be 2.8 billion RMB, which occupies 9.5% of the total investment 29.51 billion RMB in the treatment of environmental pollution of Henan province in 2014. According to Yang et al. (2018), the aggregate economic value of corn stalk burning ban policy for encouraging the comprehensive utilization of corn stalk in Henan was around about 3.4 to 3.9 billion RMB, which is more than farmers' WTA for CSR (about 2.8 billion RMB) in Henan.

The incentive of financial compensation can promote environment-related programs develop smoothly. Currently, the central and local governments of China have achieved good environmental effects from some PES programs by paying farmers compensation on environmental protection. For example, China's Sloping Land Conversion Program has reduced soil erosion and water runoff, and also generated carbon sequestration about 222 to 468 million tonnes over first ten years from 1999 which mitigates climate change (Ostwald et al., 2011). Shandong province invested 186 million RMB to promote the Atmospheric Ecological Compensation Project in 2017, resulting in air quality improvement and the average days with good air quality increases by 7.8 days from the same period last year. Hence, a reasonable compensating amount should reduce farmers' economic burden and be hoped to stimulate farmers to adopt CSR to achieve environmental benefits.

On the other hand, it should be noted that the high cost of CSR results in farmers' high expected WTA value of CSR. Therefore, should we consider downgrading the cost of CSR from another perspective? In reality, farmers pay machinery manipulators for CSR. The farmers' WTA will decrease as the charging level reduces. Government should premeditate how to reduce the charging standard of CSR, of course, the key figure at this point may become the manipulators.

In addition to economic aspect, as we assumed the technical part also limits the possibility of farmers' participation in CSR. Full amount of CSR, poor quality of stalk crushing, and slow decomposition of corn stalk significantly reduced farmers' willingness of CSR, which indicates farmers' choice is greatly influenced by technical difficulties in the process of CSR. A large amount of crop residue entering the surface soil layer and present in the seedbed will reduce crop emergence (Hicks et al., 1989), and affect crop quality at the seedling stage (Shen et al., 2012; Wu et al., 2002). In reality, among the farmers adopted CSR, 42% of them expressed worries for the difficulty of wheat sowing, 27% were fearful of the seedling emergence of subsequent wheat. Excess corn stalk can either be manually removed or more evenly distributed deeper into the soil through machine operations which may increase the indirect cost of production. Gao et al. (2019) suggested that it was possible using the upper corn stalk for off-farm utilization and the lower stalk for field fertilization. A half amount of corn stalk can significantly reduce greenhouse gas emissions, and still maintain soil fertility. From the effect of corn stalk yield on farmers' willingness to participate, we also learn that although the possibility of CSR increases with the raising of corn stalk output, once the stalk heightens to a certain value, the possibility of farmers' CSR will decrease. This result is consistent with that the likelihood of farmers' willingness to participate falls with excessive stalk amount returned to the field. Hence, we suggest that the return amount of corn stalk should be paid special attention by the government. The poor quality of crushing result in long corn stalk, and cause the large spacing among corn stalk pieces in the topsoil which may lead to serious soil water losses and affects seedling germination and rooting. Under the highly intensive agricultural district, there is limited period for corn stalk biodegradation, accordingly, the stalk is not entirely decomposed in soil, which threaten the root penetration (Li et al., 2018). The incorporated corn stalk with slow decomposition and mineralization will also cause a reduction in wheat yields due to prevent the growth and development of crop seedlings (Song et al., 2016). Moreover, the issue of slow stalk decomposition rate led to increasing farmers' WTA. The addition of chemical fertilizers (Han and He, 2010) or cellulose-decomposing bacteria (Qin et al., 2015) has been recommended to accelerate the decomposition rate of crop straw.

Farmers' recognition of CSR's values were assumed to be beneficial to promoting farmers actively adopt CSR. Indeed, farmers' recognition of soil fertility increased by CSR significantly strengthened the probability of adopting CSR and lessened farmers' WTA. Although there are some unsatisfactory aspects in the process of CSR, 59% of farmers who adopted CSR believed that CSR could improve soil fertility. This perception is also supported by Majumder et al. (2008) and Peng et al. (2016) whose researches showed that stalk return improves soil fertility, thus improving crop yields. It would be suggested that the government should expand the publicity of this benefit to make a smooth CSR development. This study focused on temporary effects of CSR on farmers' willingness to participate and expected WTA, lacking of thinking long-term effects of CSR. In fact, the impacts of CSR are long-term, for it has hysteresis impacts on soil quality or on crop yield in succeeding years (Yan et al., 2007; Malhi et al., 2011). Hence, the perennial benefits of CSR should be tested and verified in the future. As farmers continue to participate in CSR, their understanding of CSR should be more profound, accept more benefits by adopting CSR, and would be willing to contribute to protecting environment by participating in CSR as responsible citizens. In general, CSR will generate more long-term environmental benefits and be proved a sustainable agricultural production method.

We also found that farmers owning large cultivation areas of corn are more likely to get relatively lower expectations of compensated amount than in those small areas. Small planting areas will affect mechanization operation (Deininger et al., 2017) and enlarge production costs because of the decreased production efficiency (Jabarin and Epplin, 1994). Hence, boosting large-scale cultivation may be conducive to promoting CSR development.

China had produced 781 million tonnes of crop residues in 2016 (Fang et al., 2019) 16% of residues is still not used (China's People's Daily, 2017) which means about 125 million tonnes of crop straws may be thrown away or openly burned. Furthermore, about 58 million tonnes of corn stalks were burned (Hong et al., 2016), which accounts for 46% of these openly burned and discarded crop straw, and causes significant environmental burden (Chen et al., 2018; Hong et al., 2016). The high ratio of burned corn stalk implies a huge potential for corn stalk utilization in China. Incorporating corn stalk into the field instead of open burning has become the preferred method that has been greatly recommended by the government and scientists under the command-and-control measures of straw burning ban policy (Li et al., 2018). Although 91% of total respondents have returned corn stalk to the field in our survey, at least 45% of them were passive, who may be the potential farmers choosing field open burning of corn stalk. To make sure the sustainable development of CSR in China, the economic and technical aspects are suggested to be focused accruing to our study results. Government could strengthen the PES policy to compensate and stimulate farmers to participate in CSR, and also can consider how to decrease the charging level for CSR, such as compensate the machinery manipulators to lower the farmers' compensation in future, in addition, suggest to regulate the technical standard of CSR to guide how much return amount, how crushing quality, and what methods to accelerate the decomposition rate should be implemented.

No significant differences in farmers' willingness of precipitation between the six surveyed cities. But compared farmers' WTA, Zhoukou and Hebi are significant from the other cities. Since per capital annual disposal income of rural household in Zhoukou is the lowest, that in Hebi is the highest (Henan Provincial Bureau of Statistics, 2017), the unlike willingness of the expected compensation be understood. These results and suggestions should be suitable for the Yellow-Huai River Valley and Northern corn districts. Hope this contributes and inspirits in the corn planting areas at the same latitude in the world.

5. Conclusion

In order to promote farmers to adopt CSR for environmental protection, we combine economic, technical and beneficial aspects to explore factors associated with farmers' willingness (participation and accept compensation) of CSR. This research analysis is based on survey data on 925 farmers to show how possible factors are associated with farmers' choice and their expected compensation. The findings indicate that farmers' participation possibility is more likely to go down while the cost of CSR is too high, the return amount of corn stalk is excessive, the quality of stalk crushing is poor, and the decomposing rate of stalk is slow. High cost and slow decomposing rate both increase farmers' expected compensation for CSR.

This study has significant contributions to current scholarly literature, as meager existing literature revealed why farmers are reluctant to participate in CSR. This study represents one of the first attempts to fill void by exploring the issues of economic and technical reasons are more likely to restrict farmers' choice of CSR. With no intention to deny the key role of governments' straw burning ban policy (Huang et al., 2019) and socio-economic characteristics (Jan and Akram, 2018) in influencing farmers' willingness, nevertheless, we believe that these factors are not enough to explain farmers' reluctance. Finding that economic and technical factors are critical to a clearer understanding of the choice of CSR, we have made efforts to make reasonable compensation and regulated technical standards to seek a greater extent possibility of CSR's sustainable development.

Several limitations of this study should be noted. First, the elicitation of WTA through open-ended questions is generally not the most suitable method. However, considering the farmers' vulnerability to be influenced by data showed from interviewers with high education level and farmers having own understanding of CSR, we confirmed to use this elicitation method in our survey. Thus, more elicitation methods could be tried to elicit farmers' WTA. Second, overall, this study deals only with data from one part of China, a vast country, therefore it does not represent a sufficient percentage. It will be interesting to test the results of the WTA estimates in other provinces with the same wheat corn rotation system and similar socio-economic characteristics. Moreover, the hypotheses proposed were according to the opinions of farmers' when we visit them. Considering the most important determinants, some other factors or suggestions from farmers were not included. Hence, more practical difficulties should be paid cautions by both researchers and the governments.

CRediT authorship contribution statement

Xiaomei Yang: Data curation, Methodology, Writing - original draft. **Leilei Cheng:** Writing - review & editing. **Xianlei Huang:** Investigation. **Yang Zhang:** Software, Validation. **Changbin Yin:** Funding acquisition, Project administration. **Philippe Lebailly:** Supervision.

Declaration of competing interest

There is no conflict of interest.

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Appendix A

Table A
Pearson chi-square (Q_P) of crosstabulation of education between farmers' recognition of soil fertility, atmosphere environment and wheat growth.

Variables	Q_P	D.F.	Significant level
Education/soil	1.80	3	0.61
Education/atmosphere	33.83	3	0.00
Education/growth	1.96	3	0.58

Table B
Regression results of linear probability model.

Variables	Dependent variable willingness to participate		Dependent variable willingness to accept	
	Coefficients	t value	Coefficients	t value
COST	−0.11024***	−3.55	153.50***	7.49
AMOUNT	−0.32503***	−9.7	24.25	1.1
CRUSHING	−0.07991***	−2.6	10.90	0.54
DECOMPOSITION	−0.06777**	−2.18	63.11***	3.08
SOIL	0.13443***	3.01	−55.55*	−1.89
ATMOSPHERE	0.19600	1.46	−22.28	−0.25
GROWTH	0.01983	0.64	−42.88**	−2.1
AREA	0.04481	1.02	−42.17	−1.46
YIELD	0.00003***	2.70	−0.02**	−2.3
$YIELD^2$	−3.59E-10**	−1.98	1.58E-7	1.32
AGE	0.01749*	1.79	−3.49	−0.54
AGE^2	0.00017*	−1.83	0.02	0.35
GENDER	−0.05536*	−1.79	26.37	1.29
EDUCATION	0.00133	−0.25	−10.34***	−2.9
INCOME 1000	0.00053	−0.38	−2.22**	−2.38
ZHOUKOU	0.04678	0.96	76.55**	2.39

(continued on next page)

Table B (*continued*)

Variables	Dependent variable willingness to participate		Dependent variable willingness to accept	
	Coefficients	t value	Coefficients	t value
HEBI	−0.03736	−0.71	−96.43***	−2.79
SHANGQIU	0.00334	0.06	−48.69	−1.26
XUCHANG	−0.03588	−0.75	7.78	0.25
LUOYANG	0.03547	0.63	34.57	0.93
Constant	0.03348	0.11	988.20***	4.85

***, ** and * show significance levels at 1%, 5% and 10%, respectively.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2020.139775.

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