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Are Farmers Willing to Pay for Centralized Mode Provision of Rural Domestic Sewage Treatment? A Large-Scale Assessment in North China

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Evaluation of farmers' willingness to participate (WTPP) and willingness to pay (WTP) for the centralized mode provision (CMP) of rural domestic sewage treatment (RDST) is imperative to improve the rural environment as well as to alleviate government financial pressures. This study adopted the contingent valuation method as well as face-to-face interview questionnaires to assess rural residents' provision mode preferences, WTPP, and WTP for the CMP of RDST in China. Based on 761 samples collected from Shandong, Jilin, and Gansu provinces of China, we applied econometric models to estimate farmers' WTPP and WTP for the CMP of RDST and explore the potential influencing factors, respectively. Results show that 1) 81.87% of the farmers would be willing to contribute to CMP of RDST; 2) farmers' perceptions of the necessity of RDST, pollution of rural domestic sewage, and government propaganda significantly and positively affect their WTP; and 3) the expected WTP for CMP of RDST with the total respondents and the respondents with positive WTPP were estimated to be 7.59 USD/year and 10.10 USD/year (for a total of 20 years), accounting for 16.28 and 21.65% of construction costs, respectively. Based on these outcomes, it could be further estimated that the aggregate value was between 179.05 million USD/year and 238.26 million USD/year which implied that the farmers' WTP may be a potentially non-negligible funding source for the CMP of RDST. The enhancement of environmental awareness of farmers and strengthening of propaganda should be the next priority of the Chinese government. Priority should also be assigned to villages closer to towns when the government formulates relevant strategies and policies. The results of this study provide references for policy formulation related to broadening the funding sources in RDST and exploring farmer payment mechanisms and implications for other developing countries.

Keywords: rural domestic sewage treatment, centralized mode provision, contingent valuation method, willingness to pay, willingness to participate

1 INTRODUCTION

With economic development and population increase over the past decades, around 80% of sewage in the world has been directly discharged into the environment without treatment (Burket et al., 2018). The situation is even worse in rural areas because of limited investment, sanitation facilities, and research (Huang et al., 2021). Organic matter, nitrogen and phosphorus, coliforms, and pathogens are the main contaminants in rural domestic sewage (Latrach et al., 2018). A large amount of untreated rural domestic sewage discharged into surrounding ecosystems may not only lead to environmental problems such as water and soil pollution and affect agricultural production but also pose a potential threat to the health of rural residents and animals (Ye and Li, 2009; Lam et al., 2015; Wang et al., 2016; Elahi et al., 2017; Elahi et al., 2018).Currently, around 4.2 billion and 2.2 billion people are suffering from lack of safe drinking water and safe sanitation facilities worldwide, and about 47 and 70% of them live in rural areas, respectively (WHO/UNICEF, 2019). Consequently, rural domestic sewage treatment (RDST) is one of the crucial approaches to improve rural sanitation as well as to achieve the Sustainable Development Goals (SDGs) proposed by the United Nations.

In response to the challenge of SDG 6 "clean water and sanitation for all", RDST has aroused worldwide concerns, particularly in developing countries (Ladu and Lü, 2014; Rout et al., 2016; Latrach et al., 2018). As for China, the Chinese government proposed a three-year action plan for rural living environment improvement in 2018, which took RDST as a priority and was difficult to be addressed (The State Council of the People's Republic of China, 2018). The annual investment of the government in RDST has been gradually increasing each year, reaching 4.42 billion USD[1] in 2019. As a consequence, by the end of 2020, even though 25.5% of the administrative villages implemented RDST (China Agricultural Green Development Research Association, 2021), they still lag far behind developed countries. This implies that more extensive RDST facilities are required in the future to ensure the well-being of farmers and further improve the rural living environment. However, owing to the high investment of RDST facilities, local budget constraints and fiscal deficit are proved to be the major impediments to improving RDST in developing countries (Massoud et al., 2009; An et al., 2015; Sbahi et al., 2020).

It is widely believed among scholars that both the centralized mode (CM) and decentralized mode (DM) of RDST were the predominant approaches (Hu et al., 2017; Yu and Yu, 2019). Previous studies determined that CM was applicable to rural areas with high population density and clustered households, while DM was recommended for mountainous and hilly areas with smaller villages, scattered households, and unavailability of sewerage collection networks (Wang et al., 2011; Song et al., 2020; Li et al., 2020). In reality, more than 60% of China's rural population resides in the relatively flat eastern and central regions, which accounts for only 20% of the national territory area (National Bureau of Statistics of China, 2020). In addition, due to the characteristics of congregated residence developed over centuries, households in rural areas of China have a relatively high residential concentration, and congregated villages account for approximately 80% (Lu, 2013). Accordingly, the CM of RDST has a stronger applicability and broader coverage in the rural areas of China.

As a kind of rural public infrastructure with nonexclusive and nonrival characteristics, the CM of RDST is a typical public goods, and its primary beneficiaries are governments and rural residents. However, the centralized mode provision (CMP) of RDST as a kind of environmental improvement exercise demands massive investment with limited direct economic benefits and a long-term payoff period. Thus, environmental improvement has not always been the priority of local governments' investment willingness under the government performance assessment system with economic development as the main indicator (Fu et al., 2018). Therefore, in areas with relatively low-economic development levels and insufficient financial resources of local governments, the local government may not be able to bear considerable investments in RDST. As the primary and most direct beneficiaries of RDST, rural residents are more prone to "free-riding" due to their large number of beneficiaries. Nevertheless, sociologists believe that under the influence of moral attitudes, social norms, and collective identity, people will participate in the provision of public goods and make the provision optimum (Qian and Ying, 2014). Furthermore, studies on public goods provision revealed that the phenomenon of non-zero-value voluntary provision was significant and robust, that meant even though not all would contribute, there was a significant number of contributors, who typically contribute 40–60% of the optimal amount of public goods (Ledyard, 1995). Therefore, while the phenomenon of "free-riding" does occur, the strong "free-riding" hypothesis that "no one will contribute" was not valid (Dawes and Thaler, 1988). Fischbacher et al. (2001) demonstrated that the social preferences of participants in public goods provision were heterogeneous, and exhibited different levels of willingness to provide public goods. Relevant studies on rural public infrastructure provision have concentrated on two aspects. First, it is aimed at different research fields, including agricultural water conservation facilities (Cai et al., 2016; Yang and Wang, 2020), rural environmental protection public goods (Wang et al., 2014; Han et al., 2019), rural disaster mitigation public goods (Luo and Levi, 2013), and rural public services (Shono et al., 2014; Dai and Du, 2017). Second, it is for diverse provision subjects, involving the government, cooperatives, farmers, and their collaborative provision (Zhang et al., 2004; Wang et al., 2021). Therefore, previous studies provide a theoretical basis and robust sustentation for this study regarding the farmers' willingness to participate (WTPP) and WTP for the CMP of RDST.

Since farmers are the primary beneficiaries of rural public goods, their WTPP and WTP should be concerned when formulating relevant policies (Yi et al., 2011). Although studies on farmers' WTPP and WTP in rural public goods provision have been extensively discussed in recent years, there are still some

[1]1 USD =6.25 CNY (29 October 2021).

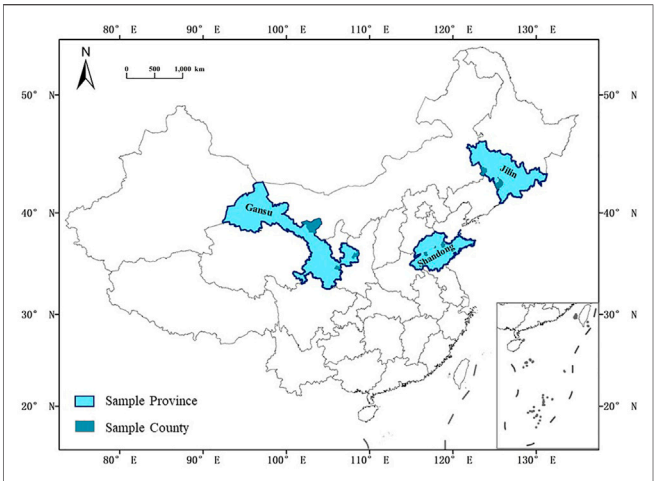

FIGURE 1 | Distribution of the study area in China.

limitations. First, most of the previous literature on RDST focused on treatment technologies or processes (Gao et al., 2017; Matos et al., 2019; Nandakumar et al., 2019), and lack of research on farmers' willingness for the CMP of RDST. Second, most studies focus on a specific area instead on a national scale (Gu et al., 2016; Wang et al., 2021). Additionally, the majority of existing studies analyzed farmers' willingness to provide/pay for public goods but without estimating the payment level (van Hoang et al., 2013; Wang et al., 2019). Ultimately, and most importantly, most emphasis was devoted to the farmers' socio-economic and demographic characteristics (Byambadorj and Lee, 2019; January 2021; Elahi et al., 2022a) when exploring the influencing factors on WTPP and WTP. In areas such as rural waste management, infrastructure development, etc., farmers' individual perceptions, government effects, and distance between their house and towns/cities were shown to have significant effects on the farmers' WTPP or WTP (Mukherji et al., 2016; Han et al., 2019; Rashid and Pandit, 2020; Su et al., 2020). Nonetheless, more influential factors should be included in this study, involving individual perceptions, government effects, and geographical factors.

As aforementioned, this study extended from two perspectives on the farmers' WTPP and WTP for the CMP of RDST. First, farmers' perceptions and government effects as significant influencing factors are incorporated in the analysis. Second, this study quantitatively analyzes farmers' WTP regarding the CMP of RDST by employing an econometric model. The objectives of this study are 1) to explore the farmers' WTPP and WTP for the CMP of RDST, 2) to determine the influencing factors of their WTPP and WTP, and 3) to provide insights for the policy formulation regarding RDST as well as to promote the realization of SDGs. For the objectives of this study, we proposed the following research hypotheses:

H1: Farmers' WTPP and WTP for the CMP of RDST can be significantly and positively affected by their perception of the necessity of RDST.

H2: The higher the farmers' perception on environmental pollution of rural domestic sewage, the more likely they tend to pay.

H3: Farmers' perception of healthiness has a significant and positive effect on WTPP and WTP.

H4: Farmers exposed to government propaganda about RDST demonstrate a higher possibility of WTPP and WTP of the CMP of RDST.

H5: The distance of farmers' houses from towns/cities has a significant effect on their WTPP and WTP.

H6: Socio-economic characteristics of farmers and their households affects their WTPP and WTP.

2 MATERIALS AND METHODS

2.1 Study Area

China has a vast territory, where resource endowments are remarkably different, i.e., topographic features, climate characteristics, economic development levels, and folk customs. Compared with south China, north China has a relatively low level of economy, a high proportion of rural population, and the improvement of rural living environment needs to be further strengthened. In this study, Shandong, Jilin, and Gansu provinces (**Figure 1**) were selected as the sample provinces in north China. All these provinces have implemented the CM of RDST to a certain extent and the RDST percentage of the administrative villages in 2016 was 18, 5 and 7%, respectively.

The Shandong province, located in the eastern coastal area of China, is one of the provinces with the largest rural population, high level of economic development, and high concentration of residential areas, which is suitable for popularizing the CM of RDST. Although the rural population in Jilin and Gansu is comparatively small, the proportion of the rural population is relatively high, and the rural residences are similarly concentrated due to the fact that the two provinces are located in severe cold and arid regions of China, respectively, and portions of the area are uninhabitable. In addition, since the average annual precipitation is less, particularly in the Gansu province, the CM of RDST is also beneficial for reusing rural domestic wastewater, such as irrigation. In 2019, the rural population of these three provinces was 38.76, 11.23, and 13.63 million, respectively, accounting for approximately 11.5% of the national rural population. The per capita disposable income of rural residents was 2,844.08, 2,389.76, and 1,540.62 USD, respectively, which was less than the national average of 2,563.31 USD per year except for Shandong. The natural conditions and economic development levels of the aforementioned provinces differ significantly. Therefore, the study area is representative and can generally reflect the general situation of China. In addition, it might provide reference for other areas of China to apply the CM of RDST, as well as in other developing countries.

2.2 Survey Design and Data Collection

The data adopted for this study were obtained from the field surveys conducted in Shandong, Jilin, and Gansu provinces from September to November 2020. All of these provinces are located in the north of the Qinling–Huaihe Line, which is recognized as the geographical boundary between the north and south of China. The perception of farmers in different regions about RDST has variability, which affects the farmers' WTPP and WTP for the CMP of RDST. In order to have a general understanding of the farmers' perceptions of RDST and farmers' WTPP and WTP for the CMP in China, and based on the principles of scientificity, accessibility, and diversity, this study applied a combination of stratified sampling and random sampling method for data collection. With the consideration of topography, investigation cost, and feasibility, as well as trying to cover both RDST demonstration and nondemonstration countries and districts, townships and villages, sample areas were stratified and randomly selected. First, three sample countries and districts were stratified and randomly selected in each of the three sample provinces, including at least one RDST demonstration country. Secondly, three sample towns in each sample country, and three villages for each sample town were randomly selected by layers. The investigated villages were typical, for they presented dissimilar levels of socio-economic development, industries, topography and geomorphology, climate features, and cultures. Lastly, 8–10 farmers were interviewed by random sampling in each selected village. Furthermore, respondents of this survey were permanent residents of the village and the main members of their respective households, therefore most of them have the capacity to determine their WTPP and WTP for the CMP of RDST.

With the objective of obtaining the data of farmers' WTPP and WTP, this study employed a face-to-face survey questionnaire. The presurvey was conducted in Hefei, Anhui province, in August 2020, which belongs to the central region of China. Based on the results of this presurvey, the questionnaire was improved to ensure comprehensibility and clarity. Thereafter, a modified questionnaire was applied to conduct the formal survey in the survey area. It should be emphasized that due to variations in questionnaire design and relatively limited amount of presurvey data, the survey data of Anhui were excluded from this study. Eventually, a total of 798 questionnaires were collected by well-trained interviewers. Of which, 761 valid questionnaires were obtained after eliminating the missing values, with 95.36% effective response rate. Among them, 262, 229, and 270 questionnaires were collected from Shandong, Jilin, and Gansu provinces, respectively.

2.3 Contingent Valuation Method and Open-Ended Elicitation

According to Carson (2000), the contingent valuation method (CVM), as a survey-based method, is generally applied for attaching monetary values to environmental goods and services that are untradeable in the market. As a typical stated preference evaluation method, the CVM adopts a questionnaire that directly inquiries about the respondents' WTP of environmental goods or services, or their willingness to accept (WTA) when abandoning environmental goods or services (Peng et al., 2018). Afterwards, based on the respondents' answers, the use value or nonuse value of environmental goods or services is evaluated by the statistical analysis.

In previous studies, several scholars have applied different methods to elicit WTP of respondents, such as payment cards, iterative bidding games, dichotomous multiple-choice questions, and open-ended questions (Randall et al., 1974; Boyle and Bishop, 1988; Hanemann et al., 1991; Boyle et al., 1996). In the questionnaire of this study, the WTP section adopts an open-ended questions approach. The respondents were directly asked, "What is the maximum amount of cash you are willing to pay?", in an open-ended WTP elicitation approach. It is convenient to answer in an open-ended approach, which does not need an investigator and does not cause starting point bias (Walsh et al., 1984). The open-ended approach is valid for studies that aim to derive conservative estimates, as the conservative value provided by this approach is lower than the bidding game approach (Venkatachalam, 2004). Nevertheless, an open-ended question tends to have a high nonresponse rate and/or leads to many zero values and overestimated values as the respondents are inconclusive about how they should evaluate the environmental goods (Yang et al., 2020). After conducting the presurvey by a face-to-face interview, the nonresponse rate for the open-ended questions obtained in this survey was meager. In addition, because RDST has been implemented in China for several years, farmers are clearly aware that RDST is an essential approach to improving the rural living environment. Therefore, most of the respondents were able to indicate the recognition on RDST and reflect their expected WTP. For the abovementioned reasons, it is feasible to adopt the open-ended approach in this study. However, considering that CMP of RDST is generally an initial investment, the initial payment level of farmers may be underestimated, which can therefore lead to biased results. In order to ensure and improve the reliability of the research results, this study proposes a method of inquiring the farmers' payment level by installment payment, and the number of years used for the installment payment is the facility service life of the CM of RDST. Based on the field investigation and literature review, we found that the service life varies for different technological processes and facility scales, but mostly concentrated on at least 20 years, and related studies also selected 20 years as the reference (Chen et al., 2009; Luo et al., 2016). Therefore, the same parameter is employed in this study as the number of years to estimate the WTP of farmers' installment payments.

2.4 Models and Variables

This study analyzed the determinants of farmers' WTPP and WTP for the CMP of RDST by synthesizing the binary logit model and the Tobit model, respectively. These two econometric models contain the same explanatory variables in order to provide an integrated analysis of their effects on WTPP and WTP.

The binary logit model is an econometric model, which is commonly applied to analyze the potential determinants, and requires farmers to either accept or reject the hypothetical

TABLE 1 | Variable definitions and summary statistics.

Category	Variable	Definition	Mean	St. Dev
Willingness	*WTPP*	Are you willing to participate in the CMP of RDST? (1 = yes, 0 = no)	0.82	0.39
	WTP	How much are you willing to pay per year (for a total of 20 years)? (USD)	7.71	9.21
Farmers' Perception	*NECESSITY*	Do you think it is necessary to treat domestic sewage? (1 = agree, 0 = disagree)	0.71	0.46
	POLLUTION	Do you think the improperly treated domestic sewage affects the rural environment? (1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree)	3.22	1.19
	HEALTH	Do you think the improper treatment of domestic sewage affects the health of villagers? (1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree)	3.23	1.24
Government Intervention	*PROPAGANDA*	Does the government ever propagate RDST? (1 = yes, 0 = no)	0.91	0.28
Individual and Household Characteristics	*GENDER*	Respondent's gender (1 = male, 0 = female)	0.70	0.46
	AGE	Respondent's age	54.16	11.54
	EDUCATION	1 = lower than primary school, 2 = primary school, 3 = junior school, 4 = high school, 5 = college and above	2.96	0.90
	CADRE	Whether you are the village cadre? (1 = yes, 0 = no)	0.20	0.40
	HOUSEHOLD SIZE	Household population	4.45	1.65
	INCOME	Annual disposable income of rural household (thousand USD)	8.51	9.63
	CENTRALIZED MODE	Whether you already have the CM of RDST? (1 = yes, 0 = no)	0.40	0.49
	CENTRALIZATION OF WATER SUPPLY	Whether you already have centralization of water supply? (1 = yes, 0 = no)	0.82	0.38
	DISTANCE	Distance from your home to the town government. (km)	5.36	3.52
Province	*SHANDONG*	1 = Shandong, 0 = other provinces	0.34	0.48
	JILIN	1 = Jilin, 0 = other provinces	0.30	0.46
	GANSU	1 = Gansu, 0 = other provinces	0.35	0.48

environmental goods or services (Wongsasuluk et al., 2018; Lazaridou et al., 2019; Wassie and Adaramola, 2021). In this study, farmers were asked about the subjective probability of selecting the WTPP for the CMP of RDST with only two alternatives, "willing" and "unwilling." The optimal decision will be determined by each farmer on the basis of a rational combination of influencing factors, which is a typical binary decision-making problem. Therefore, the binary logit model, which is widely used to analyze such problems, is chosen in this study to determine the influences of farmers' WTPP for the CMP of RDST. For the purpose of identifying the influencing factors of farmers' WTPP for the CMP of RDST, the following binary logit regression model was developed:

$$Ln\left(\frac{p}{1-p}\right) = b_0 + b_1x_1 + b_2x_2 + \cdots\cdots + b_nx_n + \varepsilon \qquad (1)$$

where, p represents the probability that farmers' WTPP for the CMP of RDST, b_0 is the constant term, b_i is the regression coefficient of the ith explanatory variable, and ε is the error term which assumed to be normally distributed with the zero mean value and constant variance (Elahi et al., 2021; Elahi et al., 2022b).

It is believed that quantitative analysis regarding the factors affecting WTP enables to verify the effectiveness of farmers' WTP and also supports the government in formulating relevant policies (Ren et al., 2020). Since the zero-response data is unavoidable in practical surveys, the parameters may be highly biased and incoherent if the factors affecting the farmers' WTP are estimated by OLS regression or Probit models. Therefore, due to the left-censored at zero, this study adopts the Tobit model proposed by Tobin (1958), which can well resolve this problem. Additionally, according to Yan et al. (2015), a comparison was made between the two methods of estimating payment levels based on the parametric and nonparametric estimation to test the robustness of the study results. According to Yang et al. (2018), the Tobit model can be represented as follows:

$$\begin{aligned} WTP_i^* &= X_i\beta + \varepsilon_i, \varepsilon_i \sim N\left(0, \sigma^2\right) \\ WTP_i &= \begin{cases} WTP_i^*, & if WTP_i^* > 0 \\ 0, & if WTP_i^* \le 0 \end{cases} \end{aligned} \qquad (2)$$

where, WTP_i is the actual observational maximum payment amount of the CMP of RDST which is censored at zero; X_i refers to the vector of explanatory variables, β is the vectors of regression coefficients, and ε_i indicates a random disturbance term which is assumed to be normally distributed with the mean zero and constant variance sigma square (σ^2). According to Tobin (1958), the expected value of WTP_i can be expressed as follow:

$$\begin{aligned} E\left(WTP_i\right) &= Pr\left(WTP^* \le 0\right) \cdot E\left(WTP_i \backslash WTP_i = 0\right) \\ &\quad + Pr\left(WTP^* > 0\right) \cdot E\left(WTP_i \mid WTP_i > 0\right) \\ &= X_i\beta F\left(X_i\beta/\sigma\right) + \sigma f\left(X_i\beta/\sigma\right) \end{aligned} \qquad (3)$$

where F denotes the standard normal random variable's cumulative distribution function, f means the normal density function, and σ refers to the standard deviation. Furthermore, for the observations with a positive WTP, the expected value can be displayed as (Amemiya, 1973):

$$E(WTP_i \mid WTP_i > 0) = X_i\beta + \sigma\lambda(X_i\beta/\sigma) \quad (4)$$

The selection and definition of variables for the binary logit model and Tobit model which were adopted in this study are shown in **Table 1**. According to the different types of variables, they are divided into five categories. In addition to the core variable "Farmers' Perception," the dependent variable is "Willingness," and the other independent variables are classified as "Government Intervention," "Individual and Household Characteristics," and "Regional dummy variables," respectively.

3 RESULTS

3.1 Descriptive Statistics of Centralized Mode Provision of Rural Domestic Sewage Treatment

Before estimating the influencing factors, it is imperative to determine the preference of rural households for differential mode selection of RDST. **Figure 2** illustrated about 80% of the respondents preferring the CM of RDST. This result is also similar to the research results of Li (2017) in the Shaanxi province, China, which demonstrates that 73.0–86.2% of farmers desired the CM of RDST. As a consequence of this discovery, the following results will be more reliable and meaningful.

In addition, the farmers' perceptions as key variables were also presented with descriptive statistics. **Figure 3** showed that approximately 71% of rural households perceived the necessity of RDST, which demonstrated that the farmers in the study area had relatively high perception of rural domestic sewage. Similarly, both the farmers' perceptions of pollution and healthiness of RDST appeared at a relatively high level. Among all the respondents, 407 and 408 respondents strongly agreed or somewhat agreed that rural domestic sewage is polluting the environment and harming rural residents, which accounted for 53.48 and 53.61%, respectively. Additionally, farmers' perceptions varied minimally among the three provinces.

3.2 Farmers' Willingness to Participate for Centralized Mode Provision of Rural Domestic Sewage Treatment and its Determinants

3.2.1 Responses of Willingness to Participate

As shown in **Table 2**, although most of the respondents demonstrate their WTPP for the CMP of RDST, there are still 18.13% of the remaining farmers explicitly refused. Among them, the Jilin province has the lowest proportion of WTPP respondents, which is 72.05%, while Shandong and Gansu are relatively higher than that in Jilin, which is 88.55 and 83.70%, respectively.

3.2.2 Determinants of Respondents' Willingness to Participate for Centralized Mode Provision of Rural Domestic Sewage Treatment

The Stata 12.1 was applied to perform regressions. **Table 3** indicated the estimation results of the respondents' WTPP for the CMP of RDST by the binary logit model. After 7 iterations, the log likelihood has not varied at the value of −204.5383. The LR $\chi 2$ value of this model was 311.47, which is significant at the level of 1%, indicating that the coefficients are not equal to zero for the independent variables. There were 13 independent variables included in the binary logit model, involving 9 independent variables which indicated significant effects at 1%, 5%, and 10% level, respectively.

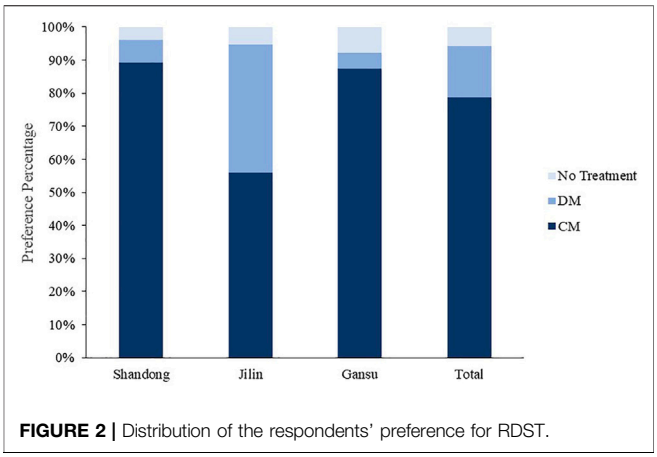

FIGURE 2 | Distribution of the respondents' preference for RDST.

"*NECESSITY*" and "*POLLUTION*" have a significant positive effect on the farmers' WTPP for the CMP of RDST. It means that the greater the perceived necessity of the domestic sewage treatment, or the more serious the pollution of domestic sewage is, the greater will be the probability of farmers' WTPP for the CMP of RDST. Related studies also verified this result (Guo and Dong, 2011; Mukherji et al., 2016; Han et al., 2019). In addition, rural households who perceived higher perceptions of "*NECESSITY*" and "*POLLUTION*," the probability of their WTPP might be increased by 10.5 and 4.7%, respectively. Although "*HEALTH*" was positively correlated with the farmers' WTPP for the CMP of RDST, it was not statistically significant.

"*PROPAGANDA*" shows a positive and significant influence on the farmers' WTPP for the CMP of RDST, which has a consistency with Su et al. (2020), which means that the farmers who have been exposed to the government propaganda on RDST tend to show a stronger willingness. All these are attributed to the fact that government propaganda may improve public's environmental knowledge and awareness of the necessity of waste treatment (Han et al., 2019). The average marginal effect indicates that for the farmers who have been exposed to government propaganda, the probability of their WTPP for the CMP of RDST is approximately 10.3% higher than that of the farmers who have not been exposed.

Regression results show that "*AGE*" has a significant negative influence on the farmers' WTPP for the CMP of RDST. It can be explained that the younger farmer has a greater probability of WTPP. Oppositely, "*EDUCATION*" indicates a significant positive influence. This implies that the higher the education levels of farmers, the greater is the possibility of the farmer's WTPP for the CMP of RDST. In related studies by other scholars (Byambadorj and Lee, 2019; Zhang et al., 2020), it has been

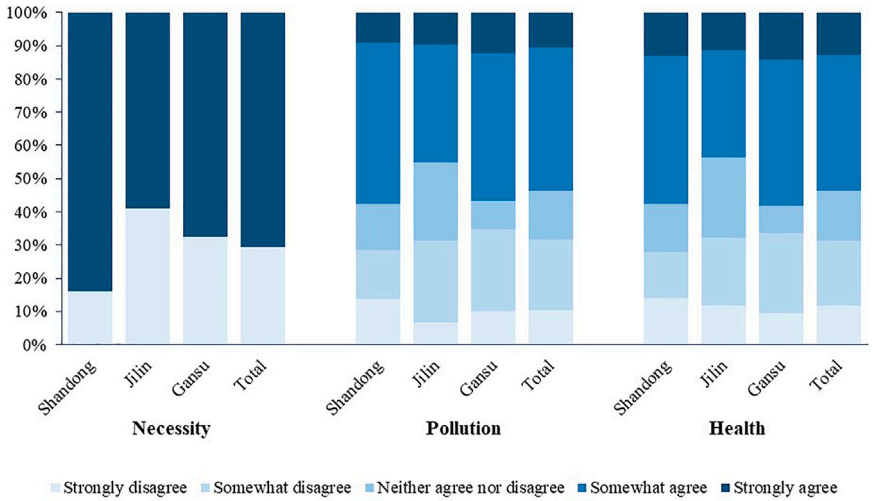

FIGURE 3 | Distribution of the farmers' perceptions.

TABLE 2 | Farmers' WTPP for the CMP of RDST.

Province	Index	WTPP	
		Yes	No
Shandong	Frequency	232	30
	Ratio (%)	88.55	11.45
Jilin	Frequency	165	64
	Ratio (%)	72.05	27.95
Gansu	Frequency	226	44
	Ratio (%)	83.70	16.30
Total	Frequency	623	138
	Ratio (%)	81.87	18.13

proved that "*AGE*" and "*EDUCATION*" have a significant effect on the farmers' willingness.

"*CADRE*" is another factor that significantly influences the farmers' WTPP for the CMP of RDST with a positive sign. With the responsibility undertaken as cadre, they are more likely to participate in the CMP of RDST, and this finding is also corroborated by Zhang et al. (2020). The average marginal effect demonstrates that the village cadre's WTPP probability for the CMP of RDST was approximately 9.8% higher than farmers with no political identities. This is probably because village cadres are the actual promoters and implementers for the government policies in rural areas who may have a higher ideological awareness and perceived value of RDST, and will accordingly be more rigorous in their compliance with government policies for the CMP of RDST.

As for "*INCOME*," it has a significant positive impact on the farmers' WTPP for the CMP of RDST, which indicates that the more disposable income the farmers have, the more likely they are willing to participate in the CMP of RDST. As the traditional experience reveals, wealthier rural households prefer more to invest in the pollution treatment (Afroz et al., 2009). The average marginal effect results show that when the farmers' income increased to 1,000 USD and other variables were constant, the probability of the farmers' WTPP for the CMP of RDST would increase by 1.6%.

"*CENTRALIZATION OF WATER SUPPLY*," also shows a significant positive influence on the farmers' WTPP for CMP of RDST. Compared with the farmers who use other domestic water (such as phreatic water and spring water, etc.), farmers who use the centralized water supply (that is, domestic water is supplied centrally by the government) have stronger WTPP for the CMP of RDST. This may be because the government provides farmers with piped water supply, while publicizing the concepts of water conservation, water resource protection, and wastewater treatment for farmers. This situation is also reflected in Mongolia (Byambadorj and Lee, 2019). Therefore, the farmers who benefit from the centralized water supply by the government are more aware of the necessity of centralized treatment of domestic sewage.

Interestingly, "*DISTANCE*" shows a significant negative impact on the farmers' WTPP for the CMP of RDST. This implies that the closer the farmers reside to the town, the more likely they are willing to participate in the CMP of RDST. There is a comparable finding in the related studies in India (Rashid and Pandit, 2020), that "*DISTANCE*" would be an essential influence factor.

3.3 Willingness to Participate for Centralized Mode Provision of Rural Domestic Sewage Treatment and its Determinants

3.3.1 Estimation of Construction Cost for Centralized Mode Provision of Rural Domestic Sewage Treatment

In this study, a construction cost analysis was performed for the CM of RDST that has been implemented in parts of the study area. **Table 4**displays that with the rising number of households, the construction cost of each household shows a trend of

TABLE 3 | Regression results for the farmers' WTPP for the CMP of RDST.

Variable	Coefficient	z-Value	Average marginal effect
NECESSITY	1.2632***	4.14	0.1049
POLLUTION	0.5676**	2.14	0.0471
HEALTH	0.1223	0.49	0.0101
PROPAGANDA	1.2436***	3.17	0.1032
GENDER	−0.2445	−0.74	−0.0203
AGE	−0.0820***	-4.95	−0.0068
EDUCATION	0.3531**	2.05	0.0293
CADRE	1.1795***	2.94	0.0979
HOUSEHOLD SIZE	0.0363	0.46	0.0030
INCOME	0.1922***	4.58	0.0160
CENTRALIZED MODE	−0.0384	−0.09	−0.0032
CENTRALIZATION OF WATER SUPPLY	0.9455***	2.75	0.0785
DISTANCE	−0.0708*	−1.91	−0.0059
JILIN	−0.3110	-0.56	−0.0258
GANSU	0.2394	0.46	0.0199
Constant	−0.1140	0.08	
Log likelihood	−204.5383		
LR χ^2 (15)	311.47***		
Pseudo R^2	0.4323		
Sample size	761		

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

increasing at the beginning and then decreasing. Treatment capacity of 501–1,000 households has the highest construction cost of the CM of RDST, which reaches the range of 1,816.96–2,184.16 USD per household. Construction cost varies accordingly due to the differences in construction scales, treatment techniques, and treatment standards adopted in each village. Therefore, for the existing CM of RDST in the study area, the average construction cost of each household is roughly calculated as 933.12 USD.

3.3.2 Responses of Willingness to Participate for Centralized Mode Provision of Rural Domestic Sewage Treatment

According to the analysis results of the Tobit model (**Table 5**), the expected value of the total observations and the truncated observations (observations with positive WTPP for the CMP of RDST) could be as high as 7.59 USD/year and 10.10 USD/year, respectively. Regarding the provincial differences, the expected value of the farmers' WTP for the CMP of RDST was 5.58 USD/year and 7.14 USD/year in the Gansu province, which was lower than that in the Shandong province and Jilin province. This difference echoes the identical tendency in the disposable income of rural residents as shown in 2.1 study area. It should be noted that a household normally adopts one mode of RDST, thus the number of rural households instead of the rural population is employed for calculating the aggregate value in this study. Based on the farmers' WTP, the number of rural households and the nonresponse rate (**Table 2**), the expected aggregate value for the mean value, the total sample and the truncated sample are estimated, respectively (**Table 5**).

TABLE 4 | Construction cost for the CM of RDST.

Treatment capacity (household)	Construction cost (thousand USD)	Average cost per household (USD)
≦300	78.4–464	412.48–1,622.24
301–500	240–800	685.6–1891.2
501–1,000	998.4–1,280	1816.96–2,184.16
≧1,001	960–1,360	606.88–646.4

3.3.3 Determinants of Respondents' Willingness to Participate for Centralized Mode Provision of Rural Domestic Sewage Treatment

The regression results of the farmers' WTP for the CMP of RDST with the Tobit model are shown in **Table 6**. In comparison to the regression results of the binary logit model of the farmers' WTPP for the CMP of RDST, there are five variables that contributed significantly to the regression results of the Tobit model of the farmers' WTP for the CMP of RDST, which are similarly significant in the aforementioned binary logit model.

"*NECESSITY*" was observed to have a significant positive effect on the farmers' WTP. Farmers who believe that rural domestic sewage need treatment have a higher WTP value than those who ignore it. Compared with those who think RDST is unnecessary, the expected probability and payment level was 15.86%, 2.22 USD/year and 3.12 USD/year higher for truncated observations and total observations, respectively. Similarly, "*PROPAGANDA*" also revealed a significant positive influence on the farmers' WTP for the CMP of RDST. The marginal effect indicated that farmers who were influenced by the government propaganda expected that WTP might increase by 3.29 USD/year for the truncated respondents and 4.64 USD/year for the total respondents than those who have not propagated. It was necessary to emphasize that when rural households are exposed to the government propaganda, it will increase the probability of WTP for the CMP of RDST by 29.31%, holding all the rest variables remain at the mean values. "*AGE*" had a significant negative effect on farmers' WTP at the level of 1%. This indicated that the younger the farmer, the more they prefer a higher WTP. Consistent with the regression results of the binary logit model, "*EDUCATION*" and "*INCOME*" have also revealed a significant positive effect ($p < 0.01$) on the farmers' WTP for the

TABLE 5 | Mean and aggregate WTP value for the CMP of RDST.

	Shandong	Jilin	Gansu	Total
Rural households (million)[a]	15.60	3.81	4.18	23.59
Mean value (USD/year)	10.64	6.79	5.64	7.71
Expected value (USD/year)[b]	10.69	6.21	5.58	7.59
Expected value (USD/year)[c]	13.02	9.36	7.14	10.10
Aggregate value (million USD/year)[d]	165.98	25.87	23.58	181.88
Aggregate value (million USD/year)[e]	166.76	23.66	23.32	179.05
Aggregate value (million USD/year)[f]	203.11	35.66	29.85	238.26

[a]*Data from the Sixth National Census of China 2010.*
[b]*Expected WTP, for total observations.*
[c]*Expected WTP, for truncated observations.*
[d]*Aggregate value for the mean value.*
[e]*Aggregate value for the expected value.*[b].
[f]*Aggregate value for the expected value.*[c].

CMP of RDST. This means that the increased farmers' education level and income are significantly promoted to a higher WTP.

4 DISCUSSIONS AND IMPLICATIONS

In light of the estimation results by the Tobit model, the expected WTP for the CMP of RDST with total respondents and truncated respondents was 7.59 USD/year and 10.10 USD/year, respectively. Thereby, the aggregate value would be estimated at 179.05 million USD and 238.26 million USD for the total households and the households excluding the negative WTP proportion (18.13%) per year. Based on MOHURD (2020), the provincial governments of Shandong, Jilin, and Gansu invested 151.64, 25.55, and 29.66 million USD in RDST of 2019, respectively. It is evident that the farmers can also be potential contributors to financial access in RDST. However, depending on the estimation of the construction cost of the existing CM of RDST, the average construction cost is roughly calculated as 933.12 USD per household with a 20-year service life of the RDST facility. According to our results on the farmers' WTP, the expected payments from households account for 16.28 and 21.65% of the total cost. This conclusion may be referred to policies formulating regarding RDST payment mechanism. In addition, it also reflects the fact that the contributions of farmers or government either cannot cover the cost of the CMP of RDST, and there is a significant funding deficit. Accordingly, in view of the actual situation, it is suggested that the financial investment at the national level should be effectively increased and establish relevant special funds. Since the expected value of the farmers' WTP in three provinces varied significantly, it is also recommended that the government should take into account the socio-economic factors and demographic factors of different regions to formulate relevant policies according to local conditions. Recently, a multitude of studies focused on the influencing factors analysis of farm households' WTPP of RDST (Fu et al., 2018; Liu and Feng, 2019; Su et al., 2020), as well as concentrating on the farmers' WTP analysis of RDST without separating the provision phase and maintenance phase (Chen et al., 2017; Xie et al., 2018), but virtually few studies have measured WTP for the CMP of RDST by applying econometric models in China.

The descriptive statistics analysis of this study revealed that only 40% of the farmers in the study area are currently accessing the CM of RDST (**Table 1**), while nearly 80% (**Figure 2**) of the investigated farmers tend to adopt the CM of RDST. This indicates

TABLE 6 | Regression results for the farmers' WTP for the CMP of RDST.

Variable	Coefficient	t-Value	Marginal effect		
			1	2	3
NECESSITY	4.35***	4.57	0.1586	2.22	3.12
POLLUTION	0.56	0.78	0.0193	0.30	0.42
HEALTH	0.85	1.25	0.0294	0.46	0.64
PROPAGANDA	7.33***	4.73	0.2931	3.29	4.64
GENDER	−0.77	−0.93	−0.0262	−0.42	−0.58
AGE	−0.11***	-3.21	−0.0039	−0.06	−0.09
EDUCATION	1.40***	3.11	0.0485	0.75	1.06
CADRE	1.19	1.35	0.0401	0.65	0.91
HOUSEHOLD SIZE	0.25	1.11	0.0085	0.13	0.19
INCOME	0.21***	5.47	0.0073	0.11	0.16
CENTRALIZED MODE	−0.82	−0.80	−0.0286	−0.44	−0.62
CENTRALIZATION OF WATER SUPPLY	1.35	1.32	0.0480	0.70	0.99
DISTANCE	−0.16	−1.59	−0.0055	−0.09	−0.12
JILIN	−2.92**	−2.16	−0.1049	−1.52	−2.14
GANSU	−3.64***	−3.19	−0.1298	−1.89	−2.66
Constant	−6.43*	−1.66			
Log likelihood	−2,354.0321				
LR χ^2 (15)	271.46***				
Pseudo R^2	0.0545				
Sample size	761				
Uncensored observations	623				

***, ** and * show significance levels at 1, 5, and 10%, respectively.*
1 Marginal effects on the probability of being censored.
2 Marginal effects on the truncated expected value (observations with positive payment level).
3 Marginal effects on the censored expected value (total observations).

that a minimum of 40% of the farmers in the study area are expected to avail themselves of the CM of RDST, which implies that in order to meet the requirements of this portion of rural residents, about 8.8 billion USD will need to be invested. In consideration of the fact that rural households may only be willing to pay for their own households, the total value (for 20 consecutive years) for this proportion of farmers is about 1.43 billion USD. However, the governments of these three provinces invested a total of about 20.8 million USD in RDST in 2019 (MOHURD, 2020), which obviously reflects an enormous funding deficiency and intense pressure on government finances. If we assume that the annual investment amount of the government remains stable and rural households contribute at a rate of 16.28%, it will take 35.4 years to raise 8.8 billion USD, which is required for the demand of the CMP of RDST in the three provinces. According to Ledyard (1995), if rural households were able to contribute between 40 and 60%, the corresponding time for raising funds would be reduced to 16.9–25.4 years. Undoubtedly, the farmers contribute significantly to the CMP of RDST, while the government remains the tremendous source of funding. However, in reality, the process of improving rural living environment, particularly RDST, will be relatively delayed if it only relies on the investments by the government and farmers. Therefore, it is suggested that various funding sources should be introduced. Social organizations, enterprises, and individuals should be encouraged to actively participate in RDST by donations or other means.

Nowadays, people are becoming more concerned about the environment with the development of the era and the improvement of living standards. However, due to the limitation of education level and other factors in rural areas, the environmental awareness of the rural residents is relatively weaker than that of the urban residents. Interestingly, the effect of environmental awareness on the farmers' WTP for the CMP of RDST in our study is positive but not significant. Therefore, the environmental awareness of the farmers should be further enhanced so as to increase the farmers' WTPP and WTP for RDST. This recommendation is also consistent with that proposed by Uthes and Matzdorf (2016) and Su et al. (2018). Thus, it is recommended to promote the farmers' self-awareness of environmental protection by means of propaganda and education, so as to form a "soft constraint" of moral concepts. In addition, it is necessary to strengthen the external restraint mechanism, such as legislation and village regulations and other "hard constraints" to reduce the farmers' pollution behavior.

Although farmers currently have perceptions of rural domestic sewage and environmental awareness to some extent, it is identified in our study that there is a relative lack of health awareness among the farmers at this stage, and a significant proportion of the farmers consider that rural domestic sewage has no or minimal impact on human health. This may be due to the fact that, although farmers discharge domestic sewage directly into the nearby water bodies that would result in a certain level of pollution, this behavior does not affect the quality of domestic water in their daily lives. Therefore, they probably consider domestic sewage contaminating the environment, but not having much impact on their health. In fact, in order to guarantee the safe drinking water in rural areas, the Chinese government has invested in the construction of numerous drinking water supply projects since 2000 (Song et al., 2020). By the end of 2019, more than 78% of the villages in China had been supplied with piped water (MOHURD, 2020), which ensures the safety of drinking water for rural residents. According to Yang et al. (2018), urban residents demonstrated a stronger awareness of health, since health conditions considerably influenced both successful career and quality of life, urban residents were increasingly inclined to allocate a certain amount of money for their health. Therefore, we recommend further raising the health awareness of the rural residents, which would make them aware of the dangers of pollution to human health and contribute to the participation and willingness in environmental management.

As the initiator and promoter of RDST, the government performs an indispensable role in the whole process of RDST, particularly in terms of propaganda. For this reason, it is recommended that the government should incorporate propaganda as a priority in its subsequent efforts to improve the farmers' environmental knowledge, perception, and awareness. Actually, since proposing the *Three-Year Action Plan for Rural Living Environment Improvement*, the central and local governments have formulated a series of policies, regulations, and institutions, and have gradually increased their efforts to propagate RDST with rural households which have demonstrated initial effectiveness. The propaganda approaches should also be broadened, a variety of propaganda methods should be promoted for various regions with heterogeneous farmers. In addition to traditional posters and brochures, new media platforms should also be promoted and introduced to diversify the propaganda about environmental protection and RDST.

In addition, the farmers' socio-economic factors that affected their WTPP and WTP should not be ignored as for the farmers' age significantly and negatively influenced their WTPP and WTP for the CMP of RDST. What is worrying is that the aging of the rural population in China continues to deepen, the aging rate in rural areas is predicted to reach 22.8% by 2030 (Fang et al., 2015; Li et al., 2020). Moreover, the population in rural areas of China has been reduced by 164.4 million and 14.21% in the last decade (National Bureau of Statistics of China, 2021). This phenomenon is attributed to the large number of rural laborers migrating to the cities (Xu and Zhang, 2021), of which mainly the young people are eager for employment and further education. Thus, the increasing aging population proportion and outmigration in rural areas of China imply that the farmers' WTPP and WTP for the CMP of RDST might be diminished, which generates more pressure on government financial investments. The positive influences of the income on WTPP and WTP demonstrate not only the affordability of high-income farmers, but also shows that these farmers are more eager to improve their living environment than those with a relatively low-income. However, marginal effects reveal that when farmers' income increases by 1,000 USD, their WTP only increases by 0.11 USD/year and 0.16 USD/year, respectively. Therefore, in the short term, it seems that there is a limit to improving the farmers' WTP for the CMP of RDST by the increasing farmers' income.

Interestingly, the distance from the farmers' residence to the town had a significant adverse effect on their WTPP. This may be

explained that the farmers who reside closer to the towns are more likely to be affected by the lifestyles of urban residents, and demonstrate a stronger desire for the living convenience of the town residents. In other words, this may also be due to the spillover effect of the improvement of urban public infrastructure on the surrounding rural areas. Therefore, villages and rural households that are close to the towns should be prioritized when formulating policies related to the CMP of RDST. In addition, villages that are located within a 5-km radius extension of the urban sewage network (Yu and Yu, 2019), the rural domestic sewage network that can be designed to connect with the municipal sewage network, and thereby to collaboratively treat domestic sewage with the town. Interestingly, distance did not have a significant effect on the WTP of rural households, which may be influenced by multiple factors such as age, education, and income.

5 CONCLUSION

According to the survey data of 761 farmers collected in Shandong, Jilin, and Gansu provinces, this study estimated the probability of the farmers' WTPP and WTP for the CMP of RDST, as well as identified the influencing factors. Our research results show that more than 79% of the investigated farmers intend to participate in the CMP of RDST, and the expected WTP for the CMP of RDST for the total respondents and the respondents with a positive WTPP to be 7.59 USD/year and 10.10 USD/year, respectively. Accordingly, when the service life of RDST facilities is set to 20 years, the farmers' payments can cover 16.28 and 21.65% of the construction costs, respectively. The present study explored and analyzed the factors influencing the farmers' WTPP and WTP for the CMP of RDST in relation to the farmers' perception, government propaganda, and individual and household characteristics. The results show that the farmers' perception of the necessity of RDST has significantly and positively affected their WTPP and WTP for the CMP of RDST, which verified **H1**. As another variable that has significantly affected the farmers' WTPP, farmers' perception of the pollution of rural domestic sewage has no significant impact on their WTP, which partially verified **H2**. However, as indicated by the results of the regression models, although the farmers' perception of healthiness positively affected their WTPP and WTP, it was not statistically significant, thus **H3** was rejected. In addition to the farmers' perceptions, we also found that the farmers exposed to the government propaganda about RDST showed relatively high levels of WTPP and WTP, which also confirmed **H4**. Interestingly, while rural households who resided closer to the towns demonstrated a stronger WTPP, they did not show a higher WTP, thus **H5** was partially validated. Simultaneously, the study results demonstrated that age, education, village cadres, income, and centralized water supply have significant effects on WTPP, and age, education, and income have also significantly contributed to their WTP. Accordingly, **H6** was partially corroborated, which means that not all the farmers' individual and household characteristics have an impact on their WTPP and WTP.

Since most of the existing studies focus on the farmers' WTPP of RDST and the willingness to maintain RDST, this study contributes significantly to the current academic literature by dividing the financial investment in RDST into a provisional phase and a maintenance phase, and reveals the influences of the farmers on the WTPP and WTP of the CMP of RDST, which complements the existing literature. In the areas with financial shortages for the provision of RDST, the results of this study provide a reference for broadening the funding sources and exploring the participation and payment mechanism of the farmers. However, due to the current WTP of the farmers for the CMP of RDST, the enhancement of environmental awareness of the farmers and strengthening of the government propaganda should be the next priority of the Chinese government. Ultimately, these recommendations may be effective in helping developing countries create a favorable rural environment and achieve the SDGs.

There are several inevitable limitations of this study that existed with most studies. First, eliciting a farmer's WTP by open-ended questions is normally not the most appropriate approach. However, since there is little literature available to provide a reference for the farmers' WTP for the CMP of RDST, and the economic development levels and geographic location vary from region to region, this study adopts open-ended questions as the first exploration in this study area. Therefore, more elicitation approaches are suggested to be employed in the subsequent studies. Secondly, the data analyzed in this study are only collected from China, so the results may not be applicable to all developing countries. Accordingly, performing relevant studies in the different developing countries with dissimilar conditions and socio-economic characteristics may enrich the results of this research field.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

JJ, ZY and CY contributed to the conception and design of the study. JJ, ZY and CY were responsible for the methodology. JJ, ZY, YZ, and BS were responsible for the data collection and analysis. TD and CY supervised these process. JJ wrote the first draft of the manuscript. JJ, ZY, YZ, BS, TD, and CY contributed to manuscript revision and approved the submitted version.

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