Evaluation of the nonmarket value of livestock and poultry feces returning to farmland utilization using CVM in Heilongjiang, China

Jiajie Shang[1,2], Yongtao Xie[1], Lifeng Guo[1], Jinxia Fan[1,2], Hongxin Liu[1,3*]

(1. *College of Engineering, Northeast Agricultural University, Harbin 150036, China*;
2. *Key Laboratory of Swine Facilities Engineering, Ministry of Agriculture and Rural Affairs, Harbin 150036, China*;
3. *College of Mechanical and Electrical Engineering, Suqian University, Suqian 223800, Jiangsu, China*)

Abstract: Aiming at a series of hot issues and topics, such as resource waste, environmental pollution, and Mollisol protection, related to the arbitrary discharge of livestock and poultry feces, livestock and poultry feces are taken as the research object, a questionnaire survey was conducted to investigate residents' cognition and willingness to pay (WTP) for the nonmarket value of livestock and poultry feces returning to farmland in Heilongjiang Province, China. The contingent valuation method (CVM) was used for the correlation analysis of WTP and socioeconomic characteristics, and correlation analysis of payment mode and socioeconomic characteristics. Meanwhile, the factors influencing WTP and payment mode were analyzed. The results show that the majority of the respondents are aware of the harmfulness of the arbitrary discharge of livestock and poultry feces and the importance of its nonmarket regeneration value. Approximately 90.09% of respondents were willing to pay for the return of livestock and poultry feces to fields. In 2020, the total value of WTP of livestock and poultry feces returning to farmland in Heilongjiang Province was 4.65 billion CNY, equivalent to 1.32% of the total agricultural production of Heilongjiang Province in the same year. And the nonmarket value of livestock and poultry feces is estimated to be 1456.69 CNY/t. The annual average WTP of rural and urban households is 286.42 CNY and 422.90 CNY per household, accounting for 0.46% and 0.52% of the average annual income of households, respectively. Therefore, the return of livestock and poultry feces to farmland utilization has a high nonmarket value. The analysis shows that the average annual household income is a significant factor in WTP, and the registered permanent residence type and the average annual household income are significant factors in payment mode. The research results should provide a scientific and theoretical basis for the government's policy and decision-making on the return of livestock and poultry feces to farmland.

Keywords: nonmarket value, livestock and poultry feces, farmland utilization, CVM, WTP
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1 Introduction

With the improvement of people's living standards, the rapid development of animal husbandry has provided people with meat, milk, and eggs, simultaneously producing a large amount of livestock and poultry feces. It is estimated that the total amount of livestock and poultry feces produced in China is approximately several billion tons each year. Arbitrary discharging or stacking is still the main treatment method, which has an impact on the atmosphere, water sources, soil, etc., and livestock and poultry feces have become one of the important sources of pollution in the ecological environment[1,2]. Moreover, the mass application of chemical fertilizer affects the quality of agricultural products in traditional farming processes and is prone to a series of problems, such as soil compaction and soil erosion. The discharge of livestock and poultry feces is considered a pollutant, but the return of livestock and poultry feces to farmland as an organic fertilizer can transform these pollutants into resources. The application of organic fertilizer can effectively enhance soil activation and permeability, alleviate soil compaction, and have a significant effect on increasing the production and income of grain and economic crops[3-5].

A literature review revealed that research on livestock and poultry feces conducted by experts in China and elsewhere has mainly focused on component analysis[6,7], organic fertilizer processing technology and methods[8-11], the design and manufacture of processing and spreading machinery and equipment[12-14], suggestions for treatment measures[15,16], and evaluations of application effects[17,18]. For the prevention and control of agricultural waste pollution, scholars from Huazhong Agricultural University of China have conducted an empirical study on its nonmarket value[19]. The willingness of rural households to pay for the prevention and control of agricultural waste pollution in Hubei Province of China was obtained, and the nonmarket value was estimated. However, the respondents were limited to rural households, and only one type of payment was provided. The research ignored important characteristics, namely, the fact that rural households generally have a low income and more free time. Meanwhile, "voluntary labor" can also be transformed to reflect the nonmarket value of the research object.

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Biographies: Jiajie Shang, PhD candidate, Engineer, research interest: agricultural system engineering, agricultural mechanization technology and equipment, Email: jazzy_shang@neau.edu.cn; **Yongtao Xie**, PhD candidate, research interest: organic fertilizer spreading mechanization technology and equipment, Email: 18678698606@163.com; **Lifeng Guo**, MS, Engineer, research interest: agricultural mechanization technology and equipment, Email: lifeng_guo@126.com; **Jinxia Fan**, PhD, Associate Professor, research interest: transformation and utilization of agricultural waste, Email: fanjxneau@neau.edu.cn.

***Corresponding author: Hongxin Liu**, PhD, Professor, research interest: resource utilization of agricultural waste, agricultural mechanization technology and equipment. College of Engineering, Northeast Agricultural University, Harbin 150030, China. Tel: +86-13054286118, Email: Lcc98@neau.edu.cn.

Ecological and environmental benefits will benefit people's production and lives by returning livestock and poultry feces to farmland. As the largest province in terms of grain production in China, Heilongjiang Province has a grain crop area of more than 13.3 million hm^2, and it is located in the core Mollisol area in Northeast China. Therefore, this paper takes Heilongjiang Province as the study area and investigates residents' willingness to pay (WTP) for the return of livestock and poultry feces to farmland from the perspective of Mollisol protection and beneficiaries. To explore and analyze WTP for the return of livestock and poultry manure and its influencing factors, estimate the non-market value of livestock and poultry manure. Correctly evaluating the non-market value of livestock and poultry manure is helpful to strengthen people's awareness of environmental protection and improve the utilization rate of livestock and poultry manure and the enthusiasm of farmland stakeholders to protect farmland. At the same time, it has practical significance for ensuring food security, protecting the ecological environment, and promoting the green and sustainable development of agriculture. In addition, related research conclusions not only provide a scientific and theoretical basis for the government to formulate and make decisions on the return of livestock and poultry feces to farmland but also provides a reference for quantifying the nonmarket value of livestock and poultry feces in other areas.

2 Research method and model selection

The contingent valuation method (CVM) was proposed and promoted by Ciriacy-Wantrup and Davis et al. in the 1950s as an effective method to evaluate the value of public goods with intangible benefits[20]. CVM is one of the most important and widely used methods for evaluating the value of public goods in ecology and resource environmental economics. A questionnaire survey is mainly used to directly investigate the economic behaviors of interviewees in a hypothetical market. After decades of development, a relatively mature theoretical evaluation method has been formed, and the CVM is widely used for value evaluation research by experts and scholars in China and elsewhere in the fields of natural resources and ecosystem services[21-23].

For example, Mutandwa et al.[24], and Chen et al.[25] researched the WTP to improve pine forest ecosystems and forest park services, respectively. Riccioli et al.[26] analyzed the recreational value of forests under different management systems. Srisawasdi et al.[27] and Oyekale et al.[28] conducted research on the WTP to improve air quality and environmental safety, respectively. Maghsood et al.[29] and Oishi et al.[30] investigated residents' cognition and WTP for flood disaster management strategies and paddy dam flood control measures under climate change, respectively. Ghanbarpour et al.[31] conducted floodplain inundation analysis combined with contingent valuation. Zhou et al.[32] studied the non-use value of urban rivers. Ao et al.[33] used the CVM to evaluate the non-use value of wetlands in Sanjiang Plain, and they calculated that the non-use value of wetlands in Sanjiang Plain was 2.4638 billion CNY/a. Based on CVM, Wang et al.[34] constructed three fuzzy evaluation models for the ecological service value of coastal wetlands, and the results showed that the three models had a high degree of consistency in their estimations. With the continuous improvement and perfection of CVM research methods, this method has been widely used in other research fields, from research on natural resources to research on species protection[35], construction waste[36], medical science[37], livestock reduction policy[38], air passenger transport[39], resource satellite[40] and other non-natural resource value.

Because multinomial logistic regression analysis is a type of nonlinear regression, it is a multiple regression analysis method for studying the relationship between binomial classification or multinomial classification results and influencing factors. Because the WTP for returning livestock and poultry feces to farmland is a typical binary choice behavior, a multinomial logistic model is used to analyze the sample data. P_i is the probability of respondents choosing "yes". Its expression is shown in Equation (1)[20].

$$P_i = \frac{\exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n)}{1 + \exp(\beta_0 + \beta_1 x_1 + \ldots + \beta_n x_n)} \quad (1)$$

where, β_0 denotes the intercept of the regression equation; x_1, x_2, x_3, …, x_n denote explanatory variables; and β_1, β_2, β_3, …, β_n denote the regression coefficients of the corresponding explanatory variables.

3 General situation of the study area and the questionnaire design

3.1 General situation of the study area

Heilongjiang Province is located in northeastern China and has the highest latitude. It stretches from 121°11'E to 135°05'E and from 43°26'N to 53°33'N. The total land area of the province is 473 000 km^2 (including the Jiagedaqi and Songling districts)[41]. According to the China Statistical Yearbook 2021[42], the total number of households in Heilongjiang in 2020 was 13.7072 million, including 9.1105 million urban households and 4.5967 million rural households.

The calculation of livestock and poultry feces yields is complicated because the discharge coefficient of livestock and poultry feces is affected by the breed, growth stage, feeding mode, and growth environment. The average discharge coefficient and feeding cycle in published research were used for calculation. If the feeding period is more than or equal to 365 d, the number of livestock and poultry is calculated based on the inventory. Otherwise, if the feeding period is less than 365 d, the number is calculated based on the number of livestock and poultry slaughtered and put on the market. In 2020, the main situation of livestock and poultry breeding in Heilongjiang Province was as follows: there were 17.9 million pigs, 3.9893 million beef cattle, 1.1687 million dairy cows, 93 thousand horses, 43 thousand donkeys, 4 thousand mules, 8.112 million sheep and 16.488 million poultry[42]. The yield of livestock manure can be calculated by Equation (2)[43].

$$L_m = \sum_{i=1}^{n} (N_i \times C_i \times D_i) \quad (2)$$

where, L_m denotes the annual discharge of livestock and poultry feces in Heilongjiang Province, kg; N_i denotes the inventory or the number of the corresponding kind of livestock or poultry slaughtered and put on the market; C_i denotes the livestock or poultry discharge coefficient of feces or urine, kg/d; D_i denotes the feeding cycle of the corresponding kind of livestock or poultry, d.

According to the calculation, the yield of feces and urine from livestock and poultry in Heilongjiang Province in 2020 was approximately 6.11×10^7 t and 2.29×10^7 t, respectively. A large amount of livestock and poultry feces can lead to water eutrophication, air and soil pollution, and damage to the ecological environment, and harmful bacteria and larvae can harm human health in various ways. Meanwhile, it affects and restricts the sustainable development of the livestock and poultry breeding industry.

3.2 Questionnaire design

In the practical application process, how to design the content of a questionnaire scientifically and reasonably is the key to the successful application of the CVM. The reason is that the design directly affects the accuracy and reliability of respondents' replies to the questions in the questionnaire. The type of questionnaire can be divided into no option, payment card, dichotomous choice, and so on[21]. The no-option method simply gives the survey content, and respondents complete the questionnaire based on their own situation. The advantage of this method is its simplicity and clarity, but its disadvantage is its low accuracy and reliability. The payment card method takes into account the upper and lower limits that respondents can accept, and then divides the interval for them to choose. This method is convenient and quick to operate, but there will be an individual lack of willingness. The dichotomous choice research method involves first asking the respondents "yes" or "no" questions about paying, and then, it further guide them to tell the reasons for their reluctance or specific WTP based on their specific choices. This method will be closer to the actual situation. This paper combines the payment card and dichotomous choice methods to carry out research based on different investigation contents.

The principles of questionnaire design should be concise and clear, survey content should be adapted to the survey method, bias should be reduced as much as possible, and information should be fully mined. The questionnaire frame was designed by referring to the CVM in different fields in China and elsewhere, striving to be comprehensive and effective. The logical topology of the questionnaire frame design and analysis is shown in Figure 1.

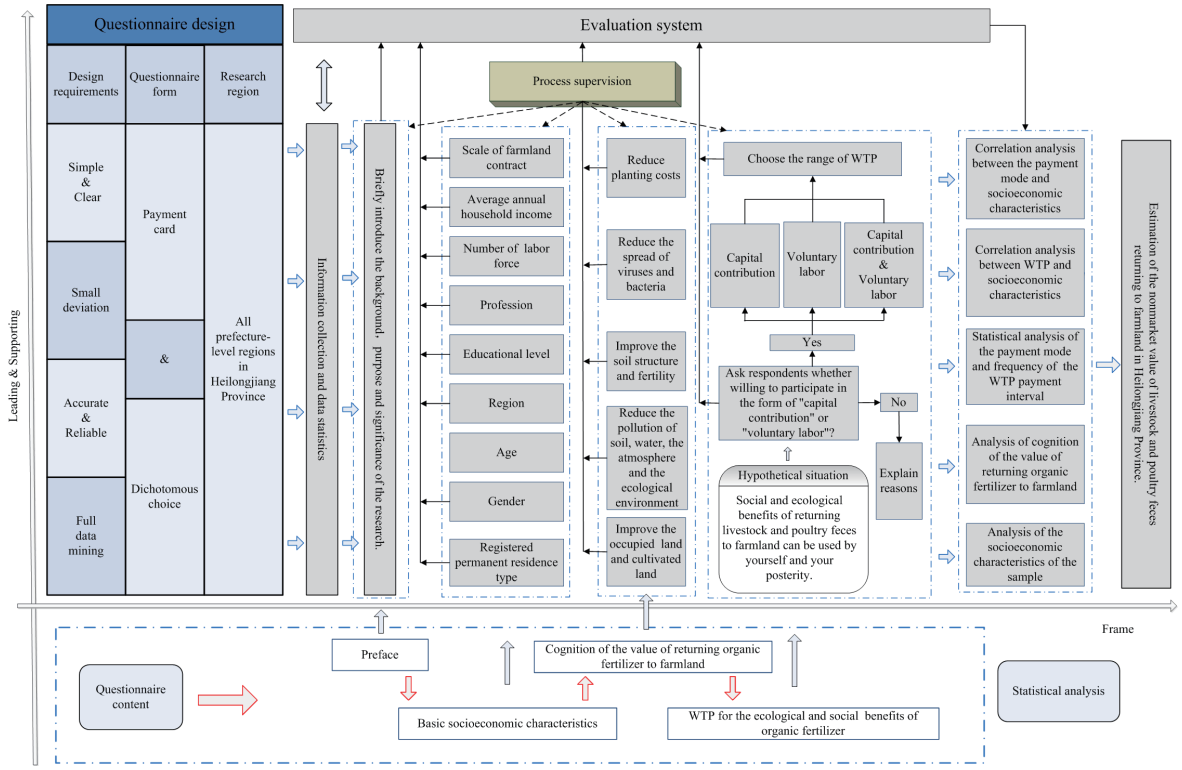

Figure 1 Logical topology of the questionnaire frame design and analysis

The questionnaire mainly consists of the following four parts:

The first part is the preface, which briefly introduces the research background, including the advantages and disadvantages of traditional chemical fertilizer application, and the impact of chemical fertilizer and organic fertilizer application on the ecological environment. Thus, the interviewees can initially understand the purpose and significance of this survey.

The second part deals with basic household information, namely, basic socioeconomic characteristics, mainly including the registered permanent residence type, gender, age, profession, educational level, average annual income of the household, and so on.

The third part is the situation of the respondents' cognition of the value of returning organic fertilizer to farmland, mainly including investigating whether they agree that returning organic fertilizer can improve occupied land and cultivated land, reduce the pollution of soil, water, the atmosphere, and the ecological environment, improve the soil structure and fertility, reduce the spread of viruses and bacteria, and reduce the planting cost. Each question sets five options for the respondents to choose from "absolute agreement", "agreement", "general agreement", "disagreement", and "absolute" disagreement.

The fourth part investigates the respondents' WTP for the ecological and social benefits of organic fertilizer. The hypothetical situation of the questionnaire is as follows: "If the ecological and social benefits generated by returning organic fertilizer to farmland can be used by yourself and your posterity, are you willing to participate in the form of a capital contribution or voluntary labor?" Then, based on the answer, to further understand the reasons for the respondents' reluctance or willingness to participate (capital contribution, voluntary labor, capital contribution+voluntary labor), according to the preliminary survey and related research results, 12 capital contribution willingness intervals and 9 acceptable voluntary labor days intervals were set.

Then, based on the four parts above, sample survey data were used to carry out the analysis of the characteristics of the social economy, analysis of the respondents' cognition of the value of returning organic fertilizer to farmland, statistical analysis of the payment and WTP interval proportion, correlation analysis of WTP and socioeconomic characteristics, and correlation analysis of the

method of payment and socioeconomic characteristics. Finally, the total value of WTP and the nonmarket value of livestock and poultry feces in Heilongjiang Province was estimated.

3.3 Sample selection and data sources

Due to the impact of COVID-19, the investigation was carried out by combining online and offline methods under the premise of avoiding or reducing personnel turnover as much as possible. The data sources mainly take advantage of the school's resource advantages, such as a large number of students, strong randomness, and wide distribution. First, online and offline training was carried out for students, so that everyone could clarify the meaning of the survey, explain each survey content one by one, and unify the survey standard. Then, on the premise of ensuring safety, one-to-one surveys, and interviews were carried out in the places where the students came from. The questionnaire is required to be completed by their family members or assisted by their family members. This investigation involves all prefecture-level regions in Heilongjiang Province, realizing the full coverage of the investigation scope.

Due to the large scope of the investigation, this paper adopts Probability Proportionate to Size Sampling (PPS sampling) method which is widely used in large-scale sample investigation. The sample size can be determined according to Equation (3)[40].

$$n = \frac{Z^2 P(1-P)(\mathrm{DEFF})}{d^2} \tag{3}$$

where, n is the number of samples; Z is the reliability of survey results (95% is selected as the confidence level, Z=1.96); P is the percentage of sample size category (P=50%); d is the expected absolute precision level (d=5%); DEFF is the design efficiency (DEFF=4). By calculation, the number of samples should reach the level of 1537 at least.

In this survey, a total of 1805 questionnaires were sent out, and 1805 were recovered. Due to the one-to-one survey, the recovery rate was 100%, and 1786 valid questionnaires were available, for an effective response rate of 98.95%. The survey was conducted from May to September 2020.

4 Data processing and statistical analysis

4.1 Analysis of the socioeconomic characteristics of the sample

There were 682 questionnaires from rural households, accounting for 38.19%, and 1104 questionnaires from urban households, accounting for 61.81%. Based on the survey results, the socioeconomic characteristics of the sample were analyzed, as listed in Table 1. Among the respondents, males accounted for 76.71%, and females accounted for 23.29%. This result was mainly due to the influence of traditional concepts and understanding of the family, resulting in a higher proportion of male respondents. In addition, the proportion of male participants in rural households was slightly higher than that in urban households, accounting for 78.89% and 75.36%, respectively. The respondents were mainly young and middle-aged, with only 1.01% of the respondents aged over 60 years old, and 82.31% of the respondents had high school education or above. The high school or above the educational level of urban households (90.49%) was significantly higher than that of rural households (69.06%). Based on the results, the sample involves employees from all walks of life, including unemployed people, people who only farm, farmers who take up other jobs in their leisure time, civil servants or employees of public institutions, private entrepreneurs, individual industrial and commercial households, workers, service personnel, military personnel, and students, accounting for 10.13%, 3.92%, 8.62%, 11.81%, 1.90%, 7.73%, 8.79%, 1.40%, and 45.69%, respectively. The average household income of the respondents was 74 300 CNY/a. The average annual income of urban households was higher than that of rural households, 82 100 CNY/a and 61 800 CNY/a, respectively. From the analysis of the survey results, the main socioeconomic characteristics of the interviewees were consistent with the overall economic and social development of Heilongjiang Province, indicating that the sample selection is reasonable and representative.

Table 1 Basic socioeconomic characteristics of the respondents

Level 1 index	Level 2 index	All respondents/%	Rural household/%	Urban household/%
Gender	Male	76.71	78.89	75.36
	Female	23.29	21.11	24.64
Age	18-30	50.90	50.00	51.45
	31-45	23.68	30.65	19.38
	46-60	24.41	18.04	28.35
	>60	1.01	1.32	0.82
Educational level	Uneducated	0.50	0.88	0.27
	Elementary school	3.02	7.92	0.00
	Junior high school	14.17	22.14	9.24
	Senior high school	23.18	23.46	23.01
	Junior college	10.08	4.40	13.59
	Undergraduate	47.42	40.76	51.54
	Postgraduate	1.62	0.44	2.36
Profession	Unemployed	10.13	8.80	10.96
	Farmer	3.92	6.89	2.08
	Farmers taking other jobs in their leisure time	8.62	18.18	2.72
	Civil servant/public institution	11.81	3.08	17.21
	Private entrepreneur	1.90	1.61	2.08
	Individual business	7.73	7.77	7.70
	Worker/service personnel	8.79	6.30	10.33
	Military personnel	1.40	1.91	1.09
	Student	45.69	45.45	45.83
Household situation	Average number of household members with an economic income	2.91	2.95	2.88
	Average annual income(ten thousand CNY/household)	7.43	6.18	8.21

4.2 Analysis of the cognition of the value of returning organic fertilizer to farmland

This part mainly investigates the respondents' cognition of the value of returning organic fertilizer to farmland. The questionnaire mainly includes five items. The contents of the survey and analysis results of the survey data are listed in Tables 2 and 3.

Table 2 Cognition of the disadvantages caused by the arbitrary discharge of livestock and poultry feces (%)

Land pollution	Air pollution	Water pollution	Spread of viruses and bacteria	Other disadvantages
74.64	58.29	78.67	57.11	9.97

According to the analysis results, most people are aware of the disadvantages caused by the arbitrary discharge of livestock and poultry feces, and their cognition level is relatively high. The degree of cognition of the four possible disadvantages from high to low is water pollution, land pollution, air pollution, and the spread of

Table 3 Cognition of the nonmarket value of livestock and poultry feces (%)

Effect	Respondents	Absolute agreement	Agreement	General agreement	Disagreement	Absolute disagreement
Can improve the occupation of land and arable land	Rural households	26.25	44.87	26.25	1.76	0.88
	Urban households	26.00	47.92	25.00	0.82	0.27
Can reduce the pollution of soil, water quality, air, and other parts of the ecological environment	Rural households	23.90	51.76	22.58	1.76	0.00
	Urban households	27.36	48.46	23.28	0.91	0.00
Can effectively improve the soil structure and fertility	Rural households	23.90	52.64	20.82	2.64	0.00
	Urban households	29.53	49.37	20.02	1.09	0.00
Can reduce the spread of viruses or bacteria	Rural households	19.06	42.08	32.70	5.28	0.88
	Urban households	25.82	36.23	31.97	5.16	0.82
Can reduce planting costs	Rural households	19.50	49.12	25.22	5.28	0.88
	Urban households	25.91	44.29	24.37	4.62	0.82

viruses and bacteria, accounting for 78.67%, 74.64%, 58.29%, and 57.11%, respectively. The proportion of those who thought that other disadvantages would occur was 9.97%, and other disadvantages mainly included waste of resources, soil compaction, impacts on human health, insect pests, impacts on the environment, food safety problems, etc. At the same time, the proportion of respondents who had a cognition of the given four kinds of disadvantages reached 35.95%.

The respondents also had a high cognition of the nonmarket regeneration value of livestock and poultry feces. The registered permanent residence type has little influence on the results of the survey, and the cognition of each indicator is relatively similar between rural households and urban households. The cognition of whether returning livestock and poultry feces to farmland can reduce the transmission of viruses or bacteria was low compared with other indicators. The proportion of rural households and urban households that chose the option of "agreement" and "absolute agreement" was 61.14% and 62.05%, respectively. However, for the remaining four items of the survey, both rural households and urban households chose the option of "agreement" and "absolute agreement", accounting for more than 68% of each item.

The analysis above shows that due to the relevant media reports and the brief introduction before the investigation, the majority of people can form a cognition of the harmfulness brought by the arbitrary discharge of livestock and poultry feces and the importance of their nonmarket regeneration value.

4.3 Correlation analysis between WTP and socioeconomic characteristics

Through the correlation analysis of WTP and socioeconomic characteristics, the proportion of residents who chose "yes" for returning livestock and poultry feces to farmland accounted for 90.09%. The correlation analysis took the respondents' willingness to make a "capital contribution" or provide "voluntary labor" to participate in returning livestock and poultry feces to farmland as the dependent variable. When the respondent is willing to participate in the form of "capital contribution" or "voluntary labor", WTP=1; otherwise, WTP=0. The name and symbols of the variables are listed in Table 4. SPSS 22.0 was used for binary logistic regression analysis of all sample data, and the analysis results are listed in Table 5.

Table 4 Definition and assignment of basic socioeconomic characteristic variables of the model

Variables	Symbol	Definition and assignment	Arithmetic mean	Standard deviation
Registered permanent residence type	X_1	Rural household=1; urban household=2	1.62	0.486
Gender	X_2	Male=1; female=2	1.23	0.423
Age	X_3	Let 18-30 be '1', 31-45 be '2', 46-60 be '3', more than 60 be '4'	1.76	0.856
Region	X_4	Harbin=1; Qiqihar=2; Mudanjiang=3; Jiamusi=4; Daqing=5; Heihe=6; Yichun=7; Suihua=8; Qitaihe=9; Jixi=10; Hegang=11; Shuangyashan=12; Daxinganling=13	5.98	3.830
Educational level	X_5	Uneducated=1; elementary school=2; junior high school=3; senior high school=4; junior college=5; undergraduate=6; postgraduate=7	4.88	1.295
Profession	X_6	Unemployed=1; farmer=2; farmer taking other jobs in leisure time=3; civil servant/public institution=4; private entrepreneur=5; individual business=6; worker/service personnel=7; military personnel=8; student=9	6.31	2.931
Number of labor force	X_7	One person=1; two persons=2; three persons=3; four persons=4; five persons=5; six persons=6; seven persons=7	2.91	0.722
Average annual household income	X_8	Less than 30 000 CNY=1; 30 000 to 60 000 CNY=2; RM 60 000 to 90 000 CNY=3; 90 000 to 120 000 CNY=4; 120 000 to 150 000 CNY=5; more than 150 000 CNY=6	2.75	1.605
Scale of household farmland contract	X_9	No arable land =1; 0 to 0.5 hm^2=2; 0.5 to 1 hm^2 =3; 1 to 1.5 hm^2 =4; 1.5 to 2 hm^2 =5; more than 2 hm^2 =6	1.94	1.491

Note: All variables were normalized in the analysis.

From the regression results, the only variable that passed the significance test was the average annual household income X_8. The other non-passing variables showed no significant effect on residents' WTP for the return of livestock and poultry feces. Consistent with the research results cited in Reference [35], the results show that the average annual household income in both studies is a significant factor influencing WTP. At the same time, the factor coefficient of the average annual household income is negative, indicating that the higher the annual household income is, the lower the willingness to participate. The reason is that the higher the income is, the higher the number of respondents from mostly urban households. The disadvantages caused by the arbitrary discharge of livestock and poultry feces exert little small impact on urban households, whereas the impact on rural households is greater.

4.4 Statistical analysis of the payment mode and proportion of the WTP payment interval

The WTP survey results of rural and urban households are

Table 5 Analysis of the correlation between socioeconomic characteristics and willingness to pay based on binary logistic regression

Variable	Symbol	Coefficient β	Standard error	Wald	df	Significance	Exp (β)
Regisstered permanent residence type	X_1	0.194	0.204	0.912	1	0.340	1.215
Gender	X_2	−0.015	0.188	0.007	1	0.935	0.985
Age	X_3	−0.352	0.364	0.935	1	0.334	0.703
Region	X_4	−0.111	0.249	0.200	1	0.655	0.895
Educational level	X_5	−0.029	0.453	0.004	1	0.949	0.971
Profession	X_6	−0.016	0.284	0.003	1	0.954	0.984
Number of labor force	X_7	0.471	0.689	0.467	1	0.494	1.602
Average annual household income***	X_8	−0.928	0.251	13.635	1	0.000	0.395
Scale of the household farmland contract	X_9	0.651	0.346	3.555	1	0.059	1.918
Constant	C	2.355	0.435	29.260	1	0.000	10.537

Note: *** indicates a correlation that is significant at the 1% level.

shown in Figure 2. For rural and urban households in the agreed payment sample, the proportion of those willing to choose "capital contribution" was 15.51% and 22.53%, respectively; the proportion of those willing to choose "voluntary labor" was 58.32% and 45.66%, respectively, and the proportion of those willing to choose in terms of "capital contribution+voluntary labor" accounted for 26.17% and 31.82%, respectively. Based on the data, the number of urban households who chose "capital contribution" is higher than that of rural households, while the number of urban households who chose "voluntary labor" is significantly lower than that of rural households. Combined with the WTP payment interval design of respondents with different payment modes, the proportion charts under different payment modes are drawn, as shown in Figure 3 (chose "capital contribution") and Figure 4 (chose "voluntary labor"), respectively[21].

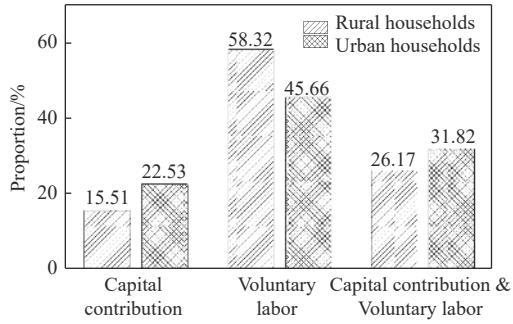

Figure 2 Proportion of different payment modes among respondents

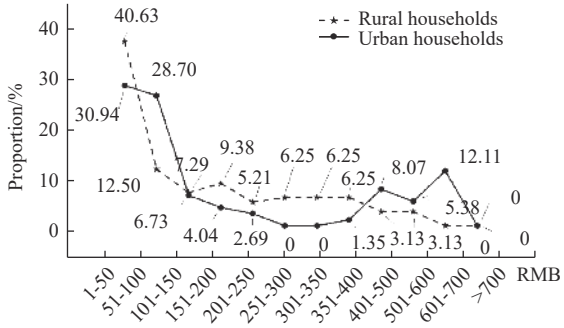

Figure 3 Proportion chart of respondents willing to choose 'capital contribution'

From Figure 3, the "capital contribution" amount accepted by most of the respondents in rural households and urban households is less than 200 CNY, accounting for 69.80% and 70.41%, respectively. From the overall perspective, with the increase in the amount of the "capital contribution", willingness presents a downward trend but with small fluctuations. Affected by household income and educational level, the proportion of urban households in the high payment zone is significantly higher than that of rural households. The WTP of more than 400 CNY accounted for 25.56% of urban households, while for rural households, it accounted for only 6.26%.

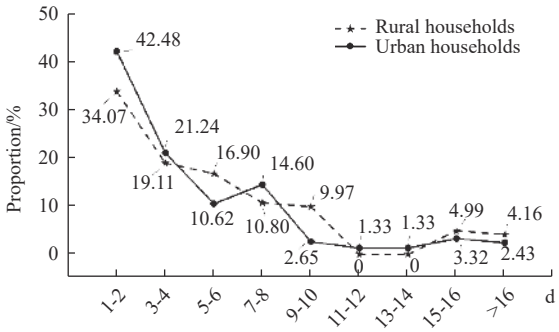

Figure 4 Proportion chart of respondents willing to choose "voluntary labor"

From Figure 4, the proportion of rural households willing to choose "voluntary labor" is similar to that of urban households. The days of "voluntary labor" decrease with the increase in payment days, and both them in a lower payment range. Among rural households and urban households, the proportion of the lowest payment days of 1-2 d is as high as 34.07% and 42.48%.

Considering that some people choose the comprehensive mode of "capital contribution+voluntary labor", universally acknowledged, the mode of "voluntary labor" cannot be directly expressed in currency. For statistical purposes, the days of "voluntary labor" should be converted into per capita daily disposable income. According to the China Statistical Yearbook 2021[42], in 2020, the average per capita daily disposable income of Heilongjiang rural residents was 44.30 CNY, and the per capita daily disposable income of urban residents was 85.25 CNY. Then, according to the data, the days of "voluntary labor" are converted into the "capital contribution" mode, and a proportion chart of respondents willing to choose the comprehensive mode of "capital contribution+voluntary labor" is drawn, as shown in Figure 5. As seen from Figure 5, when the voluntary labor days are converted to the capital contribution, the trend of the proportion distribution is obviously different from Figure 3 and Figure 4. Comparative analysis of rural and urban households, the proportion distributions in the five payment ranges of 51-100, 101-300, 151-200, 251-300, and 301-350 CNY show a great difference, and the difference in the proportion distribution is more than 10%.

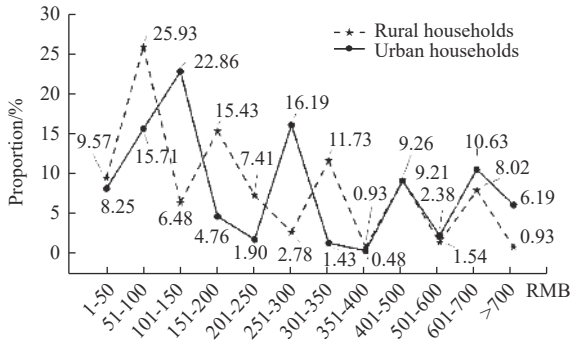

Figure 5 Proportion chart of respondents willing to participate in terms of "capital contribution+voluntary labor"

4.5 Correlation analysis between the payment mode and socioeconomic characteristics

Analyzing the correlation between the payment mode and socioeconomic characteristics, the dependent variable is the respondents' willingness to make a "capital contribution" or provide "voluntary labor" to participate to return livestock and poultry feces to farmland. Setting Y=0 when the WTP takes the form of a "capital contribution"; otherwise, Y=1 when it takes the form of "voluntary labor". During data analysis, the sample data from respondents who chose the mode of "capital contribution+voluntary labor" were excluded. The registered permanent residence type, gender, age, region, educational level, profession, the number of labor forces, average annual household income, and the scale of household farmland contracts were determined to be independent variables to conduct binary logistic regression analysis, and the analysis results are listed in Table 6. The results show that the registered permanent residence type and average annual household income are significant and negatively correlated with the payment mode. This finding indicates that for urban households, the higher their income is, the more likely they are to choose the form of "capital contribution". Because urban households generally have less leisure time, they have a higher economic ability to pay than rural households. Choosing the form of a capital contribution is simple and easy, but it is difficult to participate in the form of voluntary labor. This finding is consistent with the analysis results of the proportional distribution of the payment modes mentioned above.

Table 6 Analysis of the correlation between socioeconomic characteristics and payment modes based on binary logistic regression

Variable	Symbol	Coefficient/B	Standard error	Wald	df	Significance	Exp(β)
Registered permanent residence type***	X_1	−0.656	0.181	13.160	1	0.000	0.519
Gender	X_2	0.198	0.162	1.493	1	0.222	1.219
Age	X_3	−0.294	0.315	0.874	1	0.350	0.745
Region	X_4	0.383	0.215	3.176	1	0.075	1.466
Educational level	X_5	−0.020	0.383	0.003	1	0.957	0.980
Profession	X_6	0.425	0.227	3.513	1	0.061	1.529
Number of labor force	X_7	0.687	0.594	1.335	1	0.248	1.988
Average annual household income***	X_8	−0.726	0.219	10.981	1	0.001	0.484
Scale of the household farmland contract	X_9	−0.319	0.287	1.238	1	0.266	0.727
Constant	C	1.063	0.360	8.741	1	0.003	2.895

Note: *** indicates that the correlation is significant at the 1% level.

5 WTP and nonmarket value quantitative accounting

According to statistical data analysis, WTP is calculated for different payment modes for returning livestock and poultry feces to farmland by rural and urban households in Heilongjiang Province, as listed in Table 7. Rural and urban households' average annual WTP for a "capital contribution" are 148.96 CNY and 200.45 CNY per household, respectively. The average annual WTP for "voluntary labor" are 5.52 d and 4.74 d, respectively, and the average annual WTP for voluntary labor converted into capital contribution are 244.45 CNY and 403.90 CNY per household, respectively. The average annual WTP for "capital contribution+voluntary labor" after conversion is 461.40 CNY and 607.64 CNY per household, respectively.

Table 7 Different payment modes of livestock and poultry feces returning to farmland utilization WTP

Category	Average annual WTP for a "capital contribution"/CNY	Average annual WTP for "voluntary labor"/d	Average annual WTP for "voluntary labor" converted into "capital contribution"/CNY	Average annual WTP for "capital contribution+voluntary labor"/CNY
Rural households	148.96	5.52	244.45	461.40
Urban households	200.45	4.74	403.90	607.64

The total value of WTP of livestock and poultry feces returning to farmland utilization is shown in Equation (4)[36,44].

$$V_t = \mathrm{WTP}_R \times n_R \times P_R + \mathrm{WTP}_U \times n_U \times P_U \quad (4)$$

where, V_t denotes the total value of WTP of livestock and poultry feces. $\mathrm{WTP_R}$ and $\mathrm{WTP_U}$ denote the average annual WTP of rural households and urban households, respectively. n_R and n_U denote the number of rural households and urban households, respectively. P_R and P_U denote the payment rates of rural households and urban households. The values of each calculation parameter are listed in Table 8.

Table 8 Estimation parameters of the total value of WTP of livestock and poultry feces returning to farmland utilization based on different payment modes in Heilongjiang Province in 2020

Category	Average annual WTP/CNY	Number of households/ten thousand households	Payment rates/%
Rural households	286.42	459.67	90.76
Urban households	422.90	911.05	89.67

The nonmarket value of livestock and poultry feces is shown in Equation (5)[36,44].

$$V_n = \frac{V_t}{L_m \cdot R} \quad (5)$$

where, V_n denotes the nonmarket value per ton of livestock and poultry feces, L_m denotes the annual discharge of livestock and poultry feces in Heilongjiang Province, and R denotes the recovery rate, and its value is the sum of the safety interest rate and risk-adjusted value. The one-year time deposit interest rate of lump-sum deposits and withdrawals of the same period is selected as the safety interest rate, and the risk adjustment value is determined by the regional social and economic development level and the trend of the consumer price index[36]. The one-year time deposit interest rate of lump-sum deposits and withdrawals in 2020 is 1.5%. which is the safe interest rate. This study takes 2.3%, the annual average growth rate of the consumer price index of Heilongjiang Province in 2020, as the risk-adjusted value.

It is estimated that the total value of WTP of livestock and poultry feces returning to farmland utilization in Heilongjiang Province is 4.65 billion CNY in 2020, equivalent to 1.32% of the total agricultural production of Heilongjiang Province in the same year. In addition, the nonmarket value of livestock and poultry feces is 1456.69 CNY/t.

6 Conclusions and suggestions

1) Most of the respondents were aware of the harm caused by the arbitrary discharge of livestock and poultry feces, with a high degree of awareness. According to the survey results, 78.67%, 74.64%, 58.29%, and 57.11% of respondents had a cognition of the four disadvantages of water pollution, land pollution, air pollution, and viral and bacterial transmission, respectively. The proportion of "agreement" and "absolute agreement" with the contents that returning livestock and poultry feces to farmland can improve the occupied land and cultivated land, reduce the pollution of soil, water quality, air, and other aspects of the ecological environment, and effectively improve the soil structure and fertility was higher than 68% for both rural households and urban households.

2) Residents were able to pay for returning livestock and poultry feces to farmland, accounting for 90.09%. Among the socioeconomic characteristics investigated, only the average annual household income is a significant index influencing WTP. The proportions of rural households choosing the three payment modes of "capital contribution", "voluntary labor" and "capital contribution+voluntary labor" were 15.51%, 58.32%, and 26.17%, respectively, and the proportions of urban households choosing them were 22.53%, 45.66%, and 31.82%, respectively. The average annual WTP of rural households and urban households was 286.42 CNY and 422.90 CNY per household, respectively, which accounted for 0.46% and 0.52% of the average annual income of households, respectively. The registered permanent residence type and average annual income of the household are the significant influencing factors of the payment mode; that is, the higher the income is, the greater the likelihood that urban households will choose the form of "capital contribution".

3) The application scope of the CVM is expanded. The annual total value of WTP of livestock and poultry feces returning to farmland utilization in Heilongjiang Province in 2020 is estimated to be 4.65 billion based on the CVM, equivalent to 1.32% of the total agricultural production of Heilongjiang Province in the same year. In addition, the annual nonmarket value of livestock and poultry feces is estimated to be 1456.69 CNY/t. This study provides a reference for quantifying the nonmarket value of livestock and poultry feces in other areas and the application of this method in other fields.

4) The results provide a scientific and theoretical basis for the government's policy and decision-making regarding returning livestock and poultry feces to farmland. Therefore, it is suggested that during project implementation, local socioeconomic characteristics should be fully understood and measures should be taken based on local conditions. Regions with a high economic development level and a high WTP can be selected as pilot areas. At the same time, multiple payment modes provided can effectively improve the enthusiasm of residents to participate in the implementation and promotion of policy work. Based on the implementation of the project, a compensation fund for returning livestock and poultry feces to farmland can be set up. Under the existing compensation policy, enterprises or individuals with a high utilization rate of returning livestock and poultry feces can be given some additional compensation to make the project development in a benign and sustainable direction. In addition, it is necessary to continue to strengthen publicity and play a positive guiding role in improving residents' WTP.

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