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How does agricultural land scale affect recycling behavior of agricultural wastes: evidence from CLES

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The recycling of agricultural waste is an important measure for achieving green agricultural production. Existing studies have discussed the relationship between agricultural land scale and agricultural production from different angles, but ignored the disposal of agricultural waste. This study used China Land Economic Survey (CLES) from 2020 to 2021 and applied the probit model and the instrumental variable method to conduct the empirical analysis. The results showed a significant negative relationship between farmers' agricultural land scale and the recycling of agricultural waste. Heterogeneity analysis showed that the effect of less-developed areas was higher than that of relatively developed areas, and younger samples were less affected than the elderly. The mechanism analysis further pointed out that social norms and economic incentives can effectively promote the recycling of agricultural waste for farmers, given the scale of agricultural land. This study expands the relevant studies on agricultural waste disposal behavior, clarifies the impact and relevant mechanisms, and provides insights for realizing sustainable agricultural development.

KEYWORDS

agricultural green development, agricultural land scale, agricultural wastes, moderating effect, China

1 Introduction

The promotion of green, high-quality, and sustainable economic development has become a consensus worldwide, and promoting the green transformation of agricultural production is an important component. Over the past decade, the Chinese government has increased its determination and investments in the transformation of green agricultural production. However, for a long time, China's production has shown a characteristic of "Emphasize Usage, Disregard Recycling," and the issue of agricultural waste disposal has become increasingly prominent. It is estimated that there are over 3.2 billion pesticide packaging wastes in China each year, with a total weight exceeding 100 thousand tons (Zhao and Zhou, 2021). As one of the common sources of agricultural non-point source pollution and carbon emissions, its harm should not be underestimated. Agricultural waste not only causes visual pollution and damages the rural landscape but also leads to serious safety hazards. On the one hand, agricultural waste may scratch humans and animals because of its difficulty in decomposition (Li et al., 2021). On the other hand, residual chemicals in packaging waste can lead to secondary pollution of water, air, soil, etc. However, given the low value of recycling and utilization of agricultural waste, farmers have limited enthusiasm for adopting proper disposal practices.

In fact, existing studies on sustainable agricultural production also show a characteristic of "Emphasize Usage, Disregard Recycling." For example, the logic of reducing agricultural chemicals based on scale management has received widespread attention (Wu et al., 2018), and has been examined from different perspectives. One view is that the expansion of agricultural land scale will be beneficial in stimulating sustainable agricultural production behavior, such as reducing the use of fertilizers and pesticides and adopting environmentally friendly technology (Wu et al., 2018; Xu et al., 2018; Qin and Lu, 2020). However, the opposite viewpoint holds that a larger agricultural land scale exacerbates farmers' short-sighted production behaviors (Bambio and Bouayad, 2018). In the context of low basic soil fertility and land fragmentation in China, the expansion of agricultural land often accompanies the deepening of land fragmentation, which is not conducive to fertilizer reduction (Liu et al., 2020).

Although the above research provides valuable evidence on how agricultural land scale may impact sustainable agricultural production, existing research has rarely focused directly on the impact of agricultural land scale on waste disposal behavior. Based on the above research, we cannot help but wonder whether there is a certain connection between agricultural land scale and waste disposal behavior. Specifically, is this impact necessarily positive, just like the other environmentally friendly behaviors mentioned above?

Considering the current situation, answering the above questions can help enhance our understanding of the spillover effects of optimum-scale farm management and the potential of agricultural carbon reduction and control of agricultural source pollution. The lack of relevant empirical research is due to the lack of data on agricultural waste disposal at the micro level. Fortunately, the China Land Economic Survey (CLES) data from 2020 to 2021 provide a valuable opportunity for our study. To this end, the study used 2020–2021 CLES data, applying the probit model and instrumental variable method, and conducted heterogeneity and moderating mechanism analysis. The potential contribution of this study is as follows: First, based on family level panel data, it expands the relevant research on agricultural waste disposal behavior, providing solid evidence for clarifying the relationship between agricultural land scale and agricultural waste recycling behavior. Second, based on the unique perspective of waste disposal behavior, research on agricultural carbon reduction has expanded, and the regulatory mechanisms of economic incentives and social norms have been clarified. In summary, this study provides insights and political implications for achieving agricultural waste recycling, controlling agricultural non-point source pollution, and reducing agricultural carbon emissions.

The remainder of this paper is organized as follows. Section 2 presents the theoretical mechanism analysis, aiming to provide a detailed explanation of the relationship between the agricultural land scale and waste disposal behavior. Section 3 provides an introduction to empirical strategies, data, and variables. Section 4 focuses on showing and discussing the estimated results of empirical analysis, and further supplementing robustness analysis, heterogeneity analysis, and relevant mechanisms analysis. Finally, the final section concludes and provides political insights.

2 Theoretical mechanism

Before conducting the empirical analysis, it is necessary to determine the influential mechanism of agricultural land scale and whether farmers recycle agricultural waste. Figure 1 shows the effect of farmers' agricultural land scale on agricultural waste recycling behavior. As the agricultural land scale expands, the demand for total chemical inputs also increases significantly. Given the packaging capacity of chemical inputs, the total amount of agricultural waste will increase significantly. Therefore, a larger agricultural land scale normally results in a higher total amount of agricultural waste, leading to an increase in the total cost of recycling. Simultaneously, the decrease in the intensity of fertilizer and pesticide input per mu caused by economies of scale (Wu et al., 2018) also means that the amount of agricultural waste distributed on each mu is reduced. Overall, larger-sized farmers may face a situation in which the total amount of agricultural waste is high but scattered, further increasing the difficulty of recycling. Moreover, although additional time and effort are required by farmers for recycling, the benefits of controlling agricultural pollution and its carbon emissions are not economically exclusive, which means that it can be seen as a typical public activity with positive externalities by farmers. Farmers are prone to overlooking the increase in social costs caused by environmental pollution from agricultural production (Gao et al., 2019). Based on such public attributes, the expansion of agricultural land will undoubtedly further erode farmers' willingness and behavior to recycle agricultural waste. Therefore, existing research has found that the expansion of the agricultural land scale will exacerbate the littering behavior of pesticide package waste (Chen et al., 2022).

Owing to the additional labor and time costs that farmers need to bear when recycling agricultural waste, such behavior will generate opportunity costs, which can be compensated for through economic incentives. Economic incentives generally reduce expenditures through measures such as fees, taxes, emissions trading, and income subsidies, thereby encouraging the adoption of pollution-control measures (Wang et al., 2018), such as agricultural green subsidies (Manos et al., 2007; Yi et al., 2015; Koppmair et al., 2017), water and land rights certification (Zheng et al., 2021; Ma et al., 2022). Therefore, as economic incentives can compensate for the leisure and opportunity costs lost by farmers owing to their recycling behaviors (Li et al., 2021), their willingness to engage in proactive disposal behaviors will be stronger.

In addition to economic incentives, many studies have pointed out that informal institutions such as social norms play a crucial role in regulating the production behavior of farmers as well (Liu, 2018; Guo et al., 2020). On the one hand, there is a phenomenon of interactive learning and information sharing among farmers (Willy and Holm-Müller, 2013), so they will actively learn and imitate the production behavior of the neighborhoods. On the other hand, to evade potential social criticism or sanctions and gain recognition from neighbors, farmers need to enhance their positive image and follow the behavior exhibited by the majority in order to gain respect within neighborhoods (Abrahamse and Steg, 2013). Therefore, the behavior of the social groups in which farmers operate can also form an implicit constraint or social supervision (Yu and Li, 2020), leading to informal constraints in

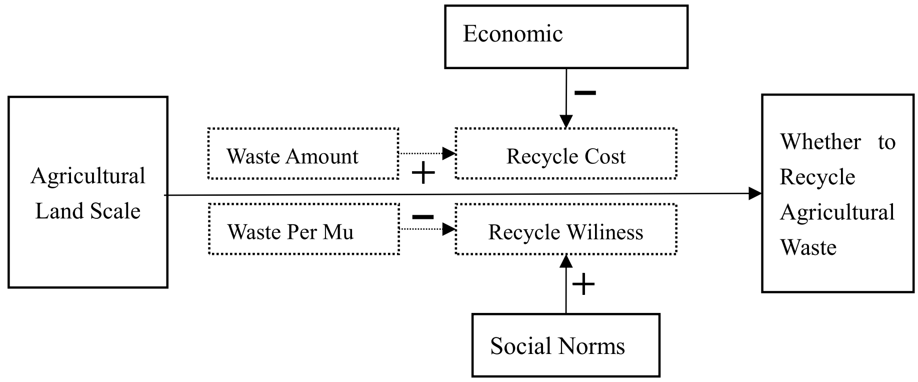

FIGURE 1
Effect of agricultural land scale on agricultural waste recycling behavior.

social norms that promote behavior at the ideological level (Li et al., 2021). Therefore, when neighbors choose to recycle their agricultural waste, they may also be encouraged to behave similarly.

Built on the above discussion, this section proposes the following assumptions:

Hypothesis 1: There is a negative correlation between the scale of agricultural land and whether farmers recycle agricultural waste.
Hypothesis 2: Economic incentives and social norms have a positive moderating effect on the impact of the agricultural land scale on the recycling behavior of agricultural waste.

3 Empirical strategy, data, and variables

3.1 Empirical strategy

Building on existing literature, we use the following regression model to estimate Equation 1:

$$Y_{it} = \beta_0 + \beta_1 land_{it} + \sum_{i=1}^{n} \gamma_i x_{it} + u_{it} \tag{1}$$

where $i(1, 2 \ldots n)$ represents the individual samples, t represents the year, Y_{it} is the concerned result variable;$land_{it}$ is the agricultural land scale;x_{it} represents the relevant controlled variables that may affect farmers' recycling behavior of agricultural waste,u_{it} is the random disturbance term. To ensure that the predicted value of y_i is always between $[0, 1]$, the probability of its distribution is:

$$\begin{cases} P\left(y = 1 \middle| x\right) = F(x, \beta) \\ P\left(y = 0 \middle| x\right) = 1 - F(x, \beta) \end{cases} \tag{2}$$

In Equation 2, the value of y is either zero or one, y follows a binomial distribution. If $F(x, \beta)$ is the standard normal cumulative distribution function, we obtain the probit model, as in Equation 3.

$$P\left(y = 1 \middle| x\right) = F\left(x, \beta\right) = \Phi\left(x^{'}\beta\right) = \int_{-\infty}^{x^{'}\beta} \Phi\left(t\right) dt \tag{3}$$

To alleviate the endogeneity issues that may exist in the model as much as possible, we adopt the instrumental variation method to test robustness.

3.2 Data source and sample processing

Our analysis used data mainly from the China Land Economic Survey (CLES) which was founded by Nanjing Agricultural University since 2020, covering 2600 households from 52 administrative villages in all 13 cities of Jiangsu Province. The reasons why we chose to use the CLES data are as followed: First, CLES is consistent with the subject of our study, it provides micro-level data on not only household information, but also behaviors of recycling agricultural waste while other common-used micro-level data such as national rural fixed observation point data, CHARLS, CHFS misses the part of agricultural waste. Second, Jiangsu province covers areas from both northern and southern part of China geographically. The economic and social environment can be various within Jiangsu province, indicating that the sample are considered representative to some extent given the complexity within Jiangsu. As CLES survey started just from the year of 2020 and ended on 2022, the data from 2022 did not bear high quality, we chose to use data from 2020 to 2021. In addition, a shorter time span also helped ensure consistency in the external environment such as policy and pandemic of the sample data, which can further reduce the endogeneity problem caused by it. After removing outliers and samples without agricultural land or production activities, 895 samples were used in our study.

3.3 Vibrable introduction

3.3.1 Dependent variable

The dependent variable in our study is the dummy variable of "whether to recycle agricultural waste," which is assigned as 1 for yes, otherwise assigned as 0. In this study, we considered pesticide packaging waste as a proxy variable for agricultural waste for the following reasons. Normally, agricultural waste may contain pesticide packaging waste, agricultural film etc., yet the data quality

TABLE 1 Basic descriptive results.

Variable	Description	Mean	Std. dev	*N*
Whether to recycle agricultural waste	Whether to recycle pesticide packaging waste (yes = 1; no = 0)	0.7620	0.4261	895
Land scale	Total farm size (mu)	55.1272	121.3209	890
Gender	Male = 1; Female = 0	0.7486	0.4341	895
Age	Age of the householder	59.3274	10.4889	895
Edu	Years of education (year)	7.1397	3.8793	895
Health	Health status (healthy = 1; unhealthy = 0)	0.8916	0.3110	895
Train	Whether received agricultural training (yes = 1; no = 0)	0.4553	0.4983	894
Income	Family total income (yuan)	19,678.8103	44,060.6475	895
Labor structure	Family's number of labor force/permanent residents	0.6590	0.3041	893
Land fragmentation	Pieces of agricultural land	7.9784	12.0416	874

Source: 2020–2021 China Land Economic Survey.

of other waste variables involved in the survey questionnaire, such as discarded agricultural films, was relatively poor. Moreover, studies pointed out that pesticide waste poses greater harm to human health and the environment than that of other agricultural wastes, and has therefore been included in the *National Hazardous Waste List* (Huang et al., 2013), making it more representative. Given the above reasons, we decided to use pesticide packaging waste to be the proxy of agricultural waste to some extent.

3.3.2 Independent variable

Our study considered farm size as the scale of agricultural land, which was measured in mu. Referring to the existing literature, the agricultural land scale took the logarithmic form in the regression to avoid potential heteroscedasticity problems (Wooldridge, 2015).

3.3.3 Other controlled variables

The selection of controlled variables followed the exogenous criterion as much as possible and contained both individual and family levels. Based on existing literature, they may affect the recycling of agricultural waste to some extent. First, the individual level contained householders' gender, age, educational level, health status, and whether they had received agricultural training in order to control the individual's stock of experience and human capital quality (Wang et al., 2018; Zhao and Zhou, 2021; Liu et al., 2022). Specifically, gender was a dummy variable (male was assigned as 1, otherwise assigned as 0), and education level was measured by householders' years of education. Health status was a dummy variable (1 for regular, healthy, and very healthy; 0 for unhealthy). Agricultural training was a dummy variable where 1 represented yes and 0 represented no.

Second, the family level control variables selected included income level, labor structure, and pieces of agricultural land. Specifically, income level refers to the total income adjusted based on the year 2020 and takes the logarithmic form in regression. The labor force structure was determined by dividing the labor force by that of permanent residents (Gao et al., 2021). These pieces of agricultural land were also considered as well in order to control land fragmentation (Xu et al., 2018; Ren et al., 2021). Finally, because the characteristics of different regions that do not change over time may be related to independent variables such as terrain and distance from the recycling facility uncovered in the questionnaire (Li et al., 2021), the city-level dummy variables were controlled. Similarly, the year-level dummy variables were also controlled as well in order to alleviate the endogeneity problem caused by time.

3.4 Descriptive analysis

Table 1 presents a descriptive analysis of the sample data. In terms of the dependent variable, the average proportion of whether to recycle agricultural waste was ∼0.76, indicating that more than three-quarters of farmers will adopt recycling behavior toward agricultural waste, leaving room for the policy goal of achieving comprehensive resource utilization of agricultural waste. In terms of independent variables, the average agricultural land scale is ∼55.13 mu. In terms of individual control variables, 74.86% of households are male, the average age is over 59 years, and the vast majority of householders have good health conditions (accounting for 89.16%); in terms of educational level, the average length of education exceeded 7 years, and only 45.53% of the respondents had received agricultural training. As for family level variables, the average total household income was around 196.7881 million yuan, the household labor structure was approximately 0.66, and the average number of land pieces was ∼7.98.

4 Empirical analysis

4.1 Probit model

To explore the impact of agricultural land scale on farmers' recycling behavior, Table 2 reports the regression results using the probit model and supplements the results of the OLS regression and two-way fixed effects model as well in order to

TABLE 2 Effect of agricultural land scale on whether to recycle agricultural waste.

	(1)		(2)	(3)
	Probit	Margin effect	OLS	Two-way fixed effect
Land scale	−0.2789***	−0.0736***	−0.0842***	−0.0663***
	(0.0444)	(0.0112)	(0.0122)	(0.0116)
Edu	0.0158		0.0054	0.0038
	(0.0155)		(0.0040)	(0.0041)
Gender	0.0474		−0.0033	0.0163
	(0.1319)		(−0.0348)	(0.0344)
Age	−0.0082		−0.0010	−0.0017
	(0.0063)		(−0.0016)	(0.0016)
Train	0.3163***		0.0922***	0.0739***
	(0.1161)		(0.0295)	(0.0291)
Health	0.2775*		0.0819*	0.0710
	(0.1593)		(0.0480)	(0.0482)
Land fragmentation	0.0029		0.0007	0.0003
	(0.0053)		(0.0017)	(0.0017)
Labor structure	0.1157		0.0456	0.0260
	(0.1665)		(0.0445)	(0.0442)
Income	−0.0033		0.0033	−0.0013
	(0.0139)		(0.0038)	(0.0037)
City fixed effect	Yes		No	Yes
Time fixed effect	Yes		No	Yes
Constant	0.6066		0.8116***	1.0868***
	(0.5044)		(0.1147)	(0.1164)
R^2	0.1601		0.0891	0.1768
N	848		871	869

*, **, and *** represent significance at the 10, 5, and 1% levels, respectively. Robust standard errors are in parentheses.

TABLE 3 Robustness test: instrumental method.

	(1)	(2)	(3)
Land scale	−0.3354***	−0.4474***	−0.3707**
	(0.1118)	(0.0871)	(0.1571)
Edu		0.0171	0.0155
		(0.0150)	(0.0163)
Gender		0.0390	0.0694
		(0.1352)	(0.1447)
Age		−0.0110	−0.0103
		(0.0072)	(0.0079)
Train		0.5203***	0.3451***
		(0.1223)	(0.1310)
Health		0.2825*	0.2868*
		(0.1495)	(0.1612)
Land fragmentation			0.0096
			(0.0123)
Labor structure			0.1289
			(0.1791)
Income			−0.0069
			(0.0154)
City fixed effect			Yes
Time fixed effect			Yes
Constant	0.7329***	1.8417***	0.7859
	(0.3431)	(0.5637)	(0.6043)
First-stage estimation			
Contracted land	0.6381***	0.6833***	0.5207***
	(0.0820)	(0.0736)	(0.0636)
F-value	21.32	64.11	56.21
N	863	883	845

*, **, and *** represent significance at the 10, 5, and 1% levels, respectively. Robust standard errors are in parentheses.

show the robustness. The results showed that the probability of farmers recycling agricultural waste was significantly negatively affected by the agricultural land scale, which is significant at the 1% level. Under the Probit model, the marginal effect results showed that when agricultural land scale expands by 1%, the probability of farmers recycling agricultural waste decreases by 7.36%, which means that the expansion of agricultural land scale will significantly inhibit the behavior of farmers recycling agricultural waste. As for other control variables, agricultural training has a positive effect on agricultural waste recycling behavior, and it is significant at the 1% level, reflecting that receiving agricultural training can encourage farmers to recycle agricultural waste. The health status of households has a positive effect on the recycling behavior of farmers and is significant at the 10% statistical level. The reason might be that better health status means a higher stock of human capital, which is conducive to recycling agricultural waste. In summary, the expansion of agricultural land has a negative impact on the recycling of agricultural waste by farmers. This is because, as the scale of agricultural land expands, the cost of field management and other expenses for farmers in the production process will significantly increase (Zhao et al., 2021). The higher cost of agricultural waste disposal inhibits farmers from adopting recycling behavior, and receiving agricultural technology training can effectively regulate and guide farmers to adopt recycling behavior.

4.2 Robustness analysis

4.2.1 Instrumental variable method analysis

Due to the inability to rule out endogeneity problems such as reverse causality in the above models, the tendency of large-scale households to adopt extensive production behaviors may allow the random interference term in the regression model related to the independent variable. Therefore, this section uses instrumental variable to further alleviate the endogeneity problem of the model. Following the approach of Wu et al. (2018), this section uses the contracted land area of farmers as an instrumental variable for agricultural land scale. Following are the detailed reasons:

According to Adamopoulos and Restuccia (2014), under the Household contract responsibility system (HCRS), the use rights of collectively owned agricultural land were allocated to rural households based on long-term contracts between the households and the village collective. The size of the agricultural land allocated to each household was typically based on the household size before the early 2000s. Built on the above introduction, it means that the contracted land area is essentially irrelevant to farmers' production experience or behaviors, thus meeting the requirements of exogeneity (Liu et al., 2022). Second, since the transfer of land use rights in China is still limited by various factors, current agricultural land scale still likely reflect that of the early 2000s (Wu et al., 2018). In our cases, the correlation coefficient of contracted area and agricultural land scale is higher than 0.7, indicating the contacted size is a suitable instrumental variable.

Building on the above discussion, Table 3 reports the robustness test of the impact of agricultural land scale on whether farmers recycled agricultural waste. Specifically, columns (1)–(3) gradually add the control variables. All models show that contracted land has a significant positive impact on the agricultural land scale, which is consistent with theoretical expectations. In addition, all F-values in the first-stage regression were >10, indicating no problem with weak instrumental variables. All models showed that the expansion of agricultural land scale has a negative impact on whether farmers recycle agricultural waste, which is significant at the 1% level. Compared with Table 2, the results of the IV method show that the inhibitory effect of agricultural land expansion is underestimated.

4.2.2 Replace dependent variable

To further test the robustness of the negative relationship between agricultural land scale and whether farmers recycle agricultural waste, this section replaces the dependent variable. According to Jiang et al. (2014), we set up the "degree of agricultural waste recycling" like this: if famers recycle both pesticide packaging and film waste, the value will be assigned as "2"; if farmers only recycle one kind of agricultural waste, the value will be assigned as "1"; if none of them are recycled, the value will be assigned as "0." Therefore, an ordered dependent variable is constructed and tested using an ordered probit model. In Table 4, columns (1)–(4) report the results of OLS, fixed-effect mole, ordered probit model, and ordered probit model-controlled fixed effects. The results showed that the scale of agricultural land had a significant negative impact on the degree of recycling behavior of agricultural waste. The above series of robustness analyses collectively reflect the fact that the expansion of agricultural land is not conducive to farmers adopting recycling behavior. Thus, Hypothesis 1, in the analysis of theoretical mechanisms, was validated.

4.3 Heterogeneity analysis

4.3.1 Heterogeneity of economic development

Previous studies have shown that the level of environmental pollution gradually decreases when economic development reaches a certain level (Jamel and Derbali, 2016). To further explore the impact of agricultural land scale on the recycling of agricultural waste, this section further analyzes the heterogeneity of economic development. Specifically, we divided the sample into economically developed and relatively underdeveloped regions based on the per capita GDP of each city in 2021.[1] As shown in Table 5, for samples from relatively underdeveloped areas, the marginal effect of the negative impact of agricultural land scale on waste recycling is −0.0909; For samples from developed regions, the marginal effect of that is −0.0558, and the negative impact on different samples is significant at the statistical level of 1%. However, compared with the entire sample, the absolute negative marginal effects experienced by economically underdeveloped regions are greater than those experienced by economically developed regions. This indicates that the recycling of agricultural waste in economically developed regions is less negatively affected by the expansion of agricultural land. The reason for this phenomenon may be that, in areas with better economic development, farmers have a stronger awareness of environmental protection. Therefore, with the expansion of the agricultural land scale, the probability of farmers in economically underdeveloped areas recycling agricultural waste is lower.

4.3.2 Heterogeneity of generation

Considering the fact that rural elderly witness a decrease in physical labor capital, making it difficult to handle heavy physical labor for waste disposal and are unlikely to be well-educated about green production behaviors, the impact of agricultural land scale on recycling behavior might be different among different generations. For this reason, we divides the sample into elderly group and younger group based on the age of 60 build on the age distribution of the whole sample. As shown in Table 6, for the younger group, the marginal effect of the negative impact of agricultural land scale on waste recycling is −0.0633, whereas for the elderly sample, the marginal effect of the negative impact is −0.1066, which is significant at the 1% statistical level. However, the absolute value of the coefficients in the elderly group was higher than that in the younger group. This means that the negative impact on the younger sample was relatively weak. This may be because young farmers have more advantages in both physical and human capital compared with the elderly group, thus increasing the probability of adopting recycling behavior for agricultural waste.

4.4 Mechanism analysis

Referring to Baron and Kenny (1986), this section demonstrates the moderating mechanism by constructing interaction terms to

1 Based on sample distribution, the former group includes Nanjing, Suzhou, Wuxi, Changzhou, Zhenjiang, Yangzhou, Taizhou, and Nantong, while the latter includes Yancheng, Huai'an, Suqian, Xuzhou, and Lian Yungang.

TABLE 4 Robustness test: ordered probit.

	(1)	(2)	(3)	(4)
	OLS	Fixed effect	OProbit	OProbit
Land scale	−0.0894***	−0.0322*	−0.1911***	−0.1146**
	(0.0213)	(0.0183)	(0.0407)	(0.0486)
Edu	0.0076	0.0096	0.0130	0.0295*
	(0.0069)	(0.0061)	(0.0144)	(0.0164)
Gender	0.0311	0.0790	0.0832	0.1851
	(0.0614)	(0.0545)	(0.1240)	(0.1381)
Age	−0.0023	−0.0050**	−0.0075	−0.0162**
	(0.0027)	(0.0025)	(0.0057)	(0.0067)
Train	0.0678	0.0692	0.1420	0.2178*
	(0.0518)	(0.0448)	(0.1087)	(0.1169)
Health	0.0552	0.0469	0.0919	0.0991
	(0.0864)	(0.0739)	(0.1645)	(0.1728)
Land fragmentation	0.0001	−0.0007	0.0008	−0.0011
	(0.0031)	(0.0029)	(0.0048)	(0.0061)
Labor structure	0.1537**	0.1494**	0.3281**	0.4450**
	(0.0785)	(0.0675)	(0.1614)	(0.1767)
Income	0.0020	−0.0035	0.0071	−0.0033
	(0.0066)	(0.0060)	(0.0127)	(0.0151)
City fixed effect		Yes		Yes
Time fixed effect		Yes		Yes
Constant	1.7177***	1.5303***	–	–
	(0.2008)	(0.2498)		
R^2	0.0395	0.3025	0.0332	0.2209
N	809	807	809	807

*, **, and *** represent significance at the 10, 5, and 1 levels, respectively. Robust standard errors are in parentheses.

test the roles of social norms and economic incentives. Therefore, we constructed the following indicators: (1) As social norms are the informal rules that govern behavior in groups and societies, normally there is no direct indicator, we referred to Li et al. (2021) and used "whether neighbors recycle agricultural waste" as the proxy variable to indicate whether one's neighborhoods prefer to recycle. Specifically, it is calculated by the proportion of recycled agricultural waste without each specific sample within the corresponding village to represent social norms. (2) For economic incentives, it generally refers to measures like fees, taxes, and income subsidies (Manos et al., 2007; Yi et al., 2015; Koppmair et al., 2017). Given the available data in the questionnaire, we chose to used the "planting subsidies". In order to make it accurate, we first adjusted the variable by the rural consumer price index published by the National Bureau of Statistic of China based on the year of 2020, and took the form of logarithm to avoid potential heteroscedasticity . Finally, we multiply the social norm and economic incentive variables with the agricultural land scale to obtain the interaction terms.

Table 7 reports the moderating effects of social norms and economic incentives, respectively. It is not difficult to find that the interaction terms concerned social norm and agricultural land scale has a significant positive impact on the probability of recycling behavior of agricultural waste, with a marginal effect of 0.1626, which is significant at the statistical level of 1%. This means that social norm can significantly promote farmers' recycling behavior of agricultural waste. It can be seen that in rural neighborhood, whether neighbors choose to recycle agricultural waste will influence on the recycling behavior of others around them (Conley and Udry, 2010; Li et al., 2021). On the other hand, the interaction term between economic incentives and agricultural land scale also significantly positively affects the recycling behavior, with a marginal effect of 0.0039. The economic coefficient is relatively low, but significant at the 1% statistical level. This indicates that government subsidies can indeed effectively relieve farmers' budget constraints, thereby encouraging them to recycle agricultural waste. However, due to the fact that the current policy of planting subsidies does not include the objectives of agricultural waste recycling, the coefficient is relatively low. To conclude, hypothesis 2 of the theoretical mechanism is verified.

5 Conclusion and policy implications

To enrich studies on agricultural green production behavior, this study focused on exploring the relationship between agricultural land scale and farmers' agricultural waste recycling behavior. Our study used 2020–2021 CLES data and applied the probit model as well as the instrumental variable method to investigate the impact of agricultural land scale on whether farmers recycle agricultural waste.

The following are the discussion and comparison on corresponding findings: First, as the agricultural land scale increases, the probability of farmers recycling agricultural waste would actually decrease. However, as we mentioned above, researches have pointed out the expansion of agricultural land scale can be beneficial in stimulating sustainable agricultural production behavior, such as the reduction of fertilizers and pesticides (Wu et al., 2018; Liu et al., 2022). This indicates that the expansion of agricultural land is not definitely positive for all types of green production behaviors, because the management cost could also rise along with the expansion (Zhao et al., 2021). As far as agricultural waste disposal is concerned, the expansion of agricultural land scale will actually raise the cost of recycling agricultural waste and increase the difficulty of recycling agricultural waste, thus reducing farmers' willingness to do so. Second, the heterogeneity analysis showed that the negative effect of samples from economically developed areas was lower than that of relatively underdeveloped areas, and the negative effect was more significant among elderly samples. Third, the mechanism analysis using interaction terms showed that given a certain agricultural land scale, social norms and economic incentives have a significant positive effect on farmers' agricultural waste recycling behavior. However, in our analysis, the role of social norms was more significant while Li et al. (2021) finds the versa. The reason on opposite findings could be that they used a dummy variable to represent economic incentives while we used the continuous variable of subsidies which is more

TABLE 5 Heterogeneity test on economic development.

	(1) Less developed	(2) Marginal effect	(3) Developed	(4) Marginal effect	(5) Full sample	(6) Marginal effect
Land scale	−0.2973***	−0.0909***	−0.2647***	−0.0558***	−0.2789***	−0.0736***
	(0.0662)	(0.0192)	(0.0620)	(0.0130)	(0.0444)	(0.0113)
Controlled variables	Yes		Yes		Yes	
City fixed effect	Yes		Yes		Yes	
Time fixed effect	Yes		Yes		Yes	
Constant	1.5421***		1.7809**		0.6066	
	(0.5842)		(0.7725)		(0.5044)	
R^2	0.1437		0.1320		0.1601	
N	451		397		848	

*, **, and *** represent significance at the 10, 5, and 1 levels, respectively. Robust standard errors are in parentheses. Each model controls for gender, age, education level, health status, agricultural training, labor structure, income, land fragmentation, and fixed effects at both city and year levels are controlled as well.

TABLE 6 Heterogeneity test on different generations.

	(1) Younger group	(2) Marginal effect	(3) Elderly group	(4) Marginal effect
Land scale	−0.2366***	−0.0633***	−0.4364***	−0.1066***
	(−0.0544)	(0.0141)	(0.0948)	(0.0220)
Controlled variables	Yes		Yes	
City fixed effect	Yes		Yes	
Time fixed effect	Yes		Yes	
Constant	0.5482		−1.7265	
	(0.7261)		(1.2795)	
R^2	0.1728		0.2044	
N	405		435	

*, **, and *** represent significance at the 10, 5, and 1% levels, respectively. Robust standard errors are in parentheses. Each model controls for gender, age, education level, health status, agricultural training, labor structure, income, land fragmentation, and fixed effects at both city and year levels are controlled as well.

TABLE 7 Regression on mechanism.

	(1) Social norm	(2) Marginal effect	(3) Economic incentive	(4) Marginal effect
Land scale	−0.7556***		−0.4086***	
	(0.1345)		(0.0733)	
Social norm* land scale	0.6361***	0.1626***	–	–
	(0.1598)	(0.0391)		
Economic incentive* land scale	–	–	0.0149**	0.0039**
			(0.0065)	(0.0017)
Controlled variables	Yes		Yes	
City fixed effect	Yes		Yes	
Time fixed effect	Yes		Yes	
R^2	0.1850		0.1661	
N	848		847	

*, **, and *** represent significance at the 10, 5, and 1% levels, respectively. Robust standard errors are in parentheses. Each model controls for gender, age, education level, health status, agricultural training, labor structure, income, land fragmentation, and fixed effects at both city and year levels are controlled as well.

accurate. This indicates that, while promoting land integration, it is necessary to promote farmers' recycling of agricultural waste from two aspects by strengthening social norms and economic incentives. Last but not the least, as for other control variables, agricultural training has a positive effect on agricultural waste recycling behavior using different models, indicating that it is vital to help farmers trained as receiving agricultural technology training can effectively regulate and guide them to adopt recycling behavior.

Based on the above results and discussion, to encourage farmers to improve their enthusiasm for recycling agricultural waste and promote their sustainable production behavior, our study puts forward the following policy recommendations: First, adhere to the orientation of optimum-scale farm management. Unlike the input of fertilizers and pesticides, the recycling behavior of agricultural waste may not be positively affected by a larger scale of agricultural land. According to our analysis, with the increase in agricultural land scale, the cost of recycling behavior of agricultural waste will also increase because of the spread of agricultural waste over a larger area, leading to more difficulty for farmers to recycle. Therefore, it is not advisable to expand the scale of agricultural land blindly. Second, we established an incentive mechanism for the recycling of agricultural waste. The government should attach importance to the designation and implementation of agricultural waste recycling policies and strengthen government supervision to eliminate free-riding. Therefore, to encourage recycling behaviors, it is necessary for the government to introduce reward and punishment policies, compulsively restrict farmers' behaviors by law, and incorporate relevant sustainable production behaviors into the policy objectives of relevant subsidies. Third, the guidance and constraints of informal institutions, such as social norms, should be strengthened to achieve parallel normative constraints and economic incentives. For example, strengthening publicity and training on the necessity of recycling agricultural waste, improving farmers' comprehensive awareness of agricultural waste, and guiding them to actively recycle themselves.

Finally, it should be pointed out that although we have explored the impact of agricultural land scale and whether farmers recycle agricultural waste from different perspectives using different methods, there are still certain shortcomings and room for expansion restrained by the availability of data. For example, the indicators could be further refined given that more detailed data, such as the categories of agricultural waste as well as the moderating variables. Moreover, the samples used were limited to the Jiangsu province covered by the CLES, which may limit the reproducibility of our study. In a nutshell, this study finds it hard to characterize the relevant variables in a more accurate way owing to the data availability. While our study provides certain level of insights of the relationship between land scale and recycling agricultural waste, answering the above questions will definitely help us further evaluate the spillover effects of agricultural land scale and provide important empirical evidence for achieving multiple political goals, such as ecological protection and ensuring agricultural production. This reveals the main direction of our subsequent analysis in the near future.

Data availability statement

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

Author contributions

JingL: Conceptualization, Funding acquisition, Writing – review & editing. JinL: Supervision, Writing – review & editing. HZ: Data curation, Methodology, Writing – original draft, Writing – review & editing. TZ: Data curation, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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