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Analyzing Cultivated Land Protection Behavior From the Perspective of Land Fragmentation and Farmland Transfer: Evidence From Farmers in Rural China

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Cultivated land protection is an important way to mitigate land pollution and realize the sustainable development of agriculture. To reveal the key factors influencing farmers' behavior of adopting cultivated land protection techniques (FBACT) from the perspective of land fragmentation and farmland transfer and to analyze the differences, a multivariate probit model is adopted to quantitatively analyze the impacts on FBACT based on field research and questionnaire surveys conducted in Jiangsu Province, China. The results show that farmland transfer promotes FBACT and that large areas of transfer-in land encourage it. Transfer-in land from outside villages reduces FBACT. The willingness of farmers to adopt protection techniques is affected by their age, their education level, family labor and the agricultural labor price, and it is hindered by land fragmentation. Encouraging farmers to transfer-in land from local villages and increasing their expectations of benefits from cultivated land protection will inspire them to adopt protection techniques. To increase the farmland transfer rate and to alleviate land fragmentation, the government should enhance the management of farmland transfer contracts and strengthen the stability of farmland use rights in farmland transfer. Promoting the transfer and integration of adjacent plots and appropriately expanding plot size will help improve FBACT.

Keywords: land pollution, cultivated land protection, farmland transfer, land fragmentation, pro-environmental agricultural techniques

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INTRODUCTION

Cultivated land is the basic element of agricultural production, and its quality is key to achieving the sustainable development of agriculture. The demand for agricultural production is growing with the expanding global population and it is challenging to meet this demand in a sustainable manner (Li et al., 2017), and the challenges for increasing agricultural productivity are related to the decline in land quality due to the low adoption of pro-environment agricultural techniques. Over the past 40 years, one-third of the cultivated land has been abandoned throughout the world (Verheijen et al., 2009). To control cultivated land abandonment, actions have been taken by international organizations, including the United Nations Educational, the Scientific and Cultural Organization (UNESCO), Institute for European Environmental Policy (IEEP), and the European Union through the Common Agricultural Policy (CAP) (Levers et al., 2018). Since

2003, food production in China has been increasing, but the predatory utilization of cultivated land has led to a series of problems, such as of soil fertility deterioration, cultivated land pollution, and ecological environmental deterioration. In China, the quality of cultivated land is successively divided into superior-quality cultivated land, high-quality cultivated land, medium-quality cultivated land-quality and low cultivated land based on grades 1–4, 5–8, 9–12 and 13–15[1]. Superior-quality cultivated land represents the smallest proportion of China's assessed cultivated land area, 2.9%. The medium and low-quality cultivated land areas represent the highest proportion, 70.5% (Progress in China's Agricultural Land Quality, 2017). Therefore, strategies for alleviating the degradation and for improving the quality of cultivated land are urgently needed. To solve these problems, in 2015, the Ministry of Agriculture and Rural Affairs of the People's Republic of China released the "Action Plan for the Protection and Promotion of Cultivated Land Quality" and has been dedicated to "encourage agricultural producers to take measures (such as increasing the application of organic fertilizer, incorporating crop straw, applying soil testing for fertilization formulas, planting green fertilizer and reducing the unreasonable input of fertilizer and pesticide) to combine land use with cultivated land protection (hereinafter referred to as CLP)." CLP includes not only fallow land but also increasing the input of agricultural factors that can improve cultivated land quality, such as planting green fertilizer, applying organic fertilizer, incorporating crop straw, and applying lime.

Farmers are the most important participants and stakeholders in the adoption of CLP techniques, and their willing embrace of such techniques has an important impact on improving cultivated land quality. The rapid development of China's economy has resulted in a large number of farmers in the agricultural labor force shifting to the nonagricultural sector, resulting in an inefficient use of farmland, land rented-out and farmland abandonment (Xu et al., 2019; Xu et al., 2020). In response to this problem, the Chinese government has actively promoted farmland transfer as an important means of solving the problem of inefficient land use and of addressing CLP. Farmland transfer refers to the farmers with the right to transfer the land use rights to other farmers or economic organizations who are capable and willing to manage it, and it involves the transfer direction (transfer-in or transfer-out land) and the transfer area (the area of transfer-in or transfer-out land). Farmland transfer can help to improve the scale and intensive management of land (Yang et al., 2021). By the end of 2020, the area of transferred land accounted for approximately 34.08% of the contracted land area in China. However, due to the implementation of the household responsibility system (HRS) and the low efficiency of farmland transfer in China, it is very difficult for farmers to gain land adjacent to their own land through a one time transfer, and they often need two or three transfers to succeed. It is also very common that one farmer operates multiple, separate plots of land. Land fragmentation is still severe in China, where the per capita cultivated land is only 0.1 ha, the mean farmland size is approximately 0.6 ha, and the number of plots per household is 5. There are still 210 million farmers whose farmland size is less than 0.6 ha. China will have a large agricultural population, and farmers will still engage in agricultural production on fragmented farmland. Xu et al. (2020) also revealed that rural households' land management scale was primarily small-scale.

Farmland transfer will lead to a differentiation in farmers' land endowments. Land fragmentation will also always exist in Chinese agricultural production and affect farmland transfer, which will in turn affect farmers' behavior of adopting CLP techniques (hereinafter referred to as FBACT). However, most previous studies have regarded land fragmentation in China as a given fact, resulting in insufficient research while most scholars use a binary discrete model to analyze the influencing factors of FBACT. Additionally, farmers may choose different CLP techniques in the agricultural product life cycle, and these techniques may affect each other. Empirical evidence is missing but essential especially for the development of CLP policy. To address this knowledge gap, this study contributes to the literature by integrating farmland transfer, land fragmentation and the heterogeneity between different CLP techniques in the analytical framework of FBACT. Additionally, a multivariate probit model is used to analyze the key influencing factors of farmers' willingness and behavior of CLP technique adoption from the perspective of farmland transfer and land fragmentation. Therefore, this paper attempts to deepen the understanding of how farmland transfer and land fragmentation affect FBACT. The results can also provide a reference for the government and academics to understand the relationship between farmland transfer, land fragmentation and FBACT.

LITERATURE AND THEORETICAL ANALYSIS

Literature Review

A large number of literatures have studied the factors that affecting the FBACT, such as the aging and social network of farmers (Yang, 2018), risk preference (Aimin, 2010), expected benefits (SriRamaratnam et al., 1987; Baumgart-Getz et al., 2012), farmers' cognition and participation willingness of CLP (Sattler et al., 2010; Ymeri et al., 2020), and agricultural laws and regulations (Lichtenberg and Ding, 2008). Guo and Wu (2016) posited that the defect in CLP policies may be an important factor of cultivated land quality deterioration. Farmers' enthusiasm for land fallow would decrease if the government ignored the quality evaluation of fallow land (Reimer et al., 2013). Additionally, some scholars have discussed the relationship of farmland size and FBACT. Saha et al. (1994) and Khanna (2001) claimed that farmers' CLP behaviors differed by farmland sizes. Ajewole

[1]According to the document "the Central Committee of the Communist Party of China and the State Council of the People's Republic of China on strengthening the quality protection of cultivated land and improving the balance between occupation and supplement." The Ministry of Natural Resources of the PRC conducted a technical evaluation based on changes in cultivated land quality caused by land use change, land consolidation, land reclamation and high-standard farmland construction in the previous year, and it divided the evaluation results into 15 grades, with grade 1 having the best quality and grade 15 having the worst quality. Under the requirement of confidentiality, the technical evaluation index system for cultivated land quality will not be published.

(2010) found that farmland size negatively influenced FBACT. However, Foster and Rosenzweig (2010) and Wang et al. (2018) pointed that the increase of farmland size was beneficial to FBACT promotion. Lu et al. (2022) revealed that farmers with larger farmland sizes were less willing to adopt CLP technique than those with small-scale farmland.

Farmland transfer in China had led to farmers' different decision-making behaviors with regard to CLP (Lu et al., 2019a). Farmers' CLP behavior on transfer-in land from nonrelatives was significantly lower than that on transfer-in land from relatives (Huang and Ji, 2012). Long and Ren (2017) noted that CLP behavior on transfer-in land would increase as farmland transfer market improved, but a quantitative empirical test was lacked. Besides, most scholars believed that stability of land use rights had a significant impact on long-term investment, including planting green manure, applying organic manure and incorporating crop straw (Jacoby et al., 2002; Qian et al., 2020). Alchian and Demsetz (1973) revealed that a long-term contract was beneficial to improve farmers' incentive to invest in farmland. Besley (1995) revealed that the instability of land use rights might inhibit farmers' enthusiasm for long-term investment. Deininger and Jin (2006) founded that the difference in expectations of land use right stability would directly affect the farmers' long-term investment behaviors. Lu et al. (2019b) claimed that a longer average length of the transfer-in land period could stimulate farmers to apply organic fertilizer, but the influence degree of the length of transfer-in land period varied with farmers' grain growing purpose and farm size, and the increase in farm size strengthened the positive effect. However, Zhong et al. (2016) argued that the impact of the stability of land use right on agricultural investment was limited.

A large number of scholars have also proven that CLP can reduce the cultivated land loss, land pollution, increase land fertility, reduce agricultural non-point pollution and improve the ecological environment in many countries (Dorfman et al., 2009; Mercks et al., 2009; Hayashi et al., 2013; Daniel et al., 2014; Lu et al., 2019b). Marc et al. (1994) revealed that CLP was a major pollution control measure. Johnston and Duck (2007) claimed that CLP could generate social benefits that were not captured by ordinary markets. Conway and Barbier (2013) founded that CLP was an important method of promoting the green transformation of agriculture. Stuart et al. (2014), Song and Pijanowski (2014) and Lu et al. (2019b) revealed that the quality of cultivated land was closely related to national food security and climate change mitigation.

Theoretical Analysis

Modern agricultural production factors of CLP are all input in the current period, and the benefits are usually not realized until the next few months or even 1–2 years. The costs of the current factor input of CLP may not be recovered in the short term. Based on the rational farmer hypothesis proposed by Schultz (1964), farmers will choose the best method of agricultural production that maximizes their agricultural profits under cultivated land resource endowment constraints. In China, most farmers are risk-averse and seek to maximize profits while minimizing production costs. Agricultural production is a part of natural production; from sowing to harvesting needs a certain period of time. It also emphasizes not to miss the farming season. Land fragmentation has resulted in many scattered plots of farmland and different distances from the home, and it affects rural households' land use and decision-making behavior of farmers with agricultural production. When moving between different farmland plots, farmers will incur time costs, labor costs and transaction costs, and more farmland plots will increase the production costs and transaction costs. Thus, small-scale, household-based farming is less attractive to Chinese farmers. Due to increased boundaries and ridges between small and dispersed plot and as a result, their willingness to adopt CLP techniques is decreased. The diversification of crop planting resulting from land fragmentation has a positive effect on increasing agricultural profits in the short term, but high-intensity land use will cause a decline in land quality. Therefore, FBACT will be directly affected by land fragmentation in China.

It is generally believed in academic circles that the moderate scale of land management plays an important role in limiting land fragmentation (Huang et al., 2020). Farmland transfer is an important method of realizing a moderate scale of land management. The area of transfer-in land not only alleviates land fragmentation but also provides the conditions for farmers to achieve scale management of farmland. In China, there are many differences in factor inputs and technique adoption among farmers with different farmland sizes (Lu et al., 2020). Compared with small-scale farmers, farmers with a larger farmland size have more financial capital (Xu et al., 2018), and they pay more attention to the sustainability of agricultural production. Most of the large-scale farmers in China have a lower time preference for future income, and they will pay more attention to the long-term income from agricultural production under the influence of the magnitude effect. Thus, the degree of adoption of CLP techniques will be higher.

Additionally, China's countryside is a human relationship society, there are many "zero rent" phenomenon in the transfer of farmland (Chen et al., 2019). Farmland transfer between farmers in the same village rarely pays the rent, and the farmland transfer contracts between farmers are mainly informal in China, with few signed written contracts that specify a period of transfer-in land (Qian and Ji, 2016). Most of the written contracts and oral agreement between farmers with a clear period of transfer-in land are also 1 year. Under the provisions of non-grain conversion of cultivated land, cultivated land cannot be used for cash crops or animal husbandry, and the farmers can only grow grain in their transfer-in land. The stability of land use rights for transfer-in land from different sources varies greatly in China. Stable land use rights of transfer-in land are conducive to improving the behavioral incentives and yield expectations of farmers, thus encouraging them to adopt CLP techniques. In addition, the transfer-in land from within a village basically derives from relatives working outside the village. Thus, Compared with the transfer-in land from outside the village, farmers have a more stable expectation of the use right of transfer-in land from within a village. Farmers also have more trust in local land and their relatives because their investment is easier to recover even if the transfer-in land use right is accidentally withdrawn. Furthermore, farmers in rural China are mostly risk averse (Lu et al., 2020), and they will consider not only profit maximization but also risk minimization when deciding whether to adopt CLP techniques.

METHODS

Binary Probit Mode

Farmers' willingness to adopt CLP techniques is a typical discrete selection variable and therefore it is difficult to express with continuous numerical values. The sorted data will be treated as a base and result in biased or inconsistent results if ordinary least squares (OLS) estimation is used. Therefore, a probit model is constructed for empirical analysis. $Y = 1$ indicates that farmers are willing to adopt CLP techniques, and $Y = 0$ indicates that they are not willing to adopt such techniques. Suppose the expression of Y^* is as follows:

$$Y^* = X\beta + \varepsilon \tag{1}$$

X represents the factors that affect the willingness of farmers to adopt CLP techniques, is the estimation coefficient of each factor, and ε is the random disturbance term. In the empirical analysis, maximum likelihood estimation is used to calculate the coefficient. The probit model can be deduced as follows:

$$P(Y = 1|X) = P(Y^* = 0|X) = P(\varepsilon > -X\beta|X) = \varphi(X\beta) \tag{2}$$

φ is the standard normal cumulative distribution function. In empirical analysis, the maximum likelihood method is used to estimate the probit model.

Multivariate Probit Model

Farmers are likely to adopt more than one CLP technique in an agricultural product life cycle. Therefore, this study adopts a multivariate probit model, which allows for correlation between the error terms of different equations, to analyze CLP behavior in Jiangsu Province, China, from the farmland transfer perspective. The multivariate probit model contains multiple binary explained variables. The specific form of the model is as follows:

$$Y_j = \begin{cases} 1, Y_j^* > 0 \\ 0, Y_j^* < 0 \end{cases} \tag{3}$$

$$Y_j^* = X\beta_j + \varepsilon_j \tag{4}$$

In **Eqs 3**, **4** above, j = 1,2,3, and 4, indicates that farmers choose straw incorporation, farmyard manure application, organic fertilizer application and deep pine farmland, respectively. Y_j^* is a latent variable, and Y_j^* is an observational variable; $if\ Y_j^* > 0$, then $Y_j = 1$, indicating that farmers choose the corresponding CLP technique. X represents the factors that affect FBACT, β_j is the estimation coefficient corresponding to each factor, and ε_j is a random disturbance term that obeys a multivariate normal distribution with a mean value of 0 and covariance of **Ω**. The covariance matrix **Ω** is as follows:

$$\Omega = \begin{bmatrix} 1 & \delta_{12} & \delta_{13} & \delta_{14} \\ \delta_{21} & 1 & \delta_{22} & \delta_{23} \\ \delta_{31} & \delta_{32} & 1 & \delta_{34} \\ \delta_{41} & \delta_{42} & \delta_{43} & 1 \end{bmatrix} \tag{5}$$

In **Eq. 5** above, the elements on the nondiagonal represent the unobservable relationship between the random disturbance terms of the four binary selection equations for the four different CLP techniques. A nonzero value of the nondiagonal terms indicates that the random disturbance terms of the four equations are related and that the multivariate probit model should be used for analysis. The value of the nondiagonal is significant and greater than 0, indicating that the different CLP techniques adopted by farmers are complementary; the opposite is substitution.

DATA

Data Sources

China's Jiangsu Province is located in the middle of the Yangtze River Delta (**Figure 1**). It covers an area of approximately 10.76 million ha and has an average elevation below 50 m. The northern subtropical monsoon climate dominates this region all year, and it has a mean annual temperature of 17.5°C and a mean annual rainfall of 1,055 mm, all of which are beneficial for agricultural production. Jiangsu has 4.58 million ha of cultivated land, and 0.057 ha of cultivated land per capita. The topography in Jiangsu is mainly plains, which cover an area of more than 7 million ha, accounting for more than 70% of the province. Economic development is not balanced across the regions of Jiangsu. Southern Jiangsu Province is one of the economically fastest growing areas in Eastern China. With geographic proximity to the most industrialized city, Shanghai, this region is renowned for its export-oriented, predominantly high-tech manufacturing industry.

Agricultural modernization is at the forefront in China's Jiangsu Province. Jiangsu Province is the main grain-producing area in China, and grain production mainly consists of rice planting. To reduce the cost of agricultural planting and to realize economics of scale in land use, the utilization rate of agricultural mechanization, scale management of farmland and the rate of farmland transfer in Jiangsu Province have been relatively high in recent years. With a few types of diversified planting, rice planting is the main survey object of this study. In agricultural production, when there is spare time, most farmers choose to engage in nonagricultural work to maximize their total income from agricultural production and nonagricultural employment.

The data used in this study were obtained from a microsurgery of farmers conducted by Nanjing Agriculture University (NAU) in Jiangsu Province, China, in 2018. There are significant differences in regional economic development and geomorphic characteristics between different regions of Jiangsu Province. In Jiangsu Province, Nantong City, Yancheng City, Yangzhou City and Taizhou City were selected as sample areas based on a comprehensive consideration of the agricultural development level of all regions. Then, one county in each city was randomly selected, four towns in each county were randomly selected, and three villages in each town were randomly selected based on the random sampling method. The household interviews mostly carried out with the head of household because the head of the household have main responsibility for overall household management and farming system.

The questionnaire included the following aspects: 1) household characteristics, such as the age of the respondent, education of family members, the number of family members in the labor force, the distribution of family labor time, and the employment of family

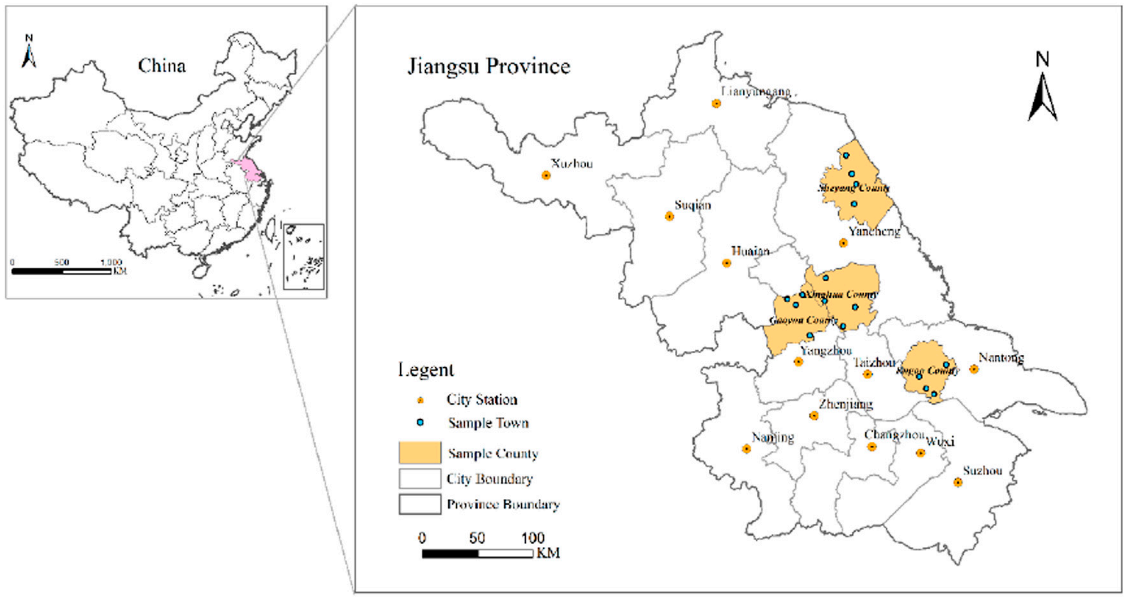

FIGURE 1 | Location of jiangsu province in China and the study area.

members; 2) basic information on farmland, such as the farmland size, number of plots, distance of plots from the home, and farmland transfer situation; and 3) the CLP situation, such as the willingness to adopt CLP techniques and the expected benefits from the adopted CLP techniques. To ensure the quality of the questionnaire, before the formal investigation, the researchers conducted several intensive trainings, explained the relevant content of the questionnaire, and clarified the meaning of relevant aspects. The formal investigation was conducted through face-to-face interactions between an investigator and farmers, and the investigator completed the questionnaires on behalf of the farmers. This method prevented any misunderstandings that may have arisen if the farmers themselves completed the questionnaires. After the survey was completed, the questionnaires were examined, cross-checked and compiled. A total of 270 valid questionnaires were obtained, yielding a recovery rate of 90%.

Data Description

Table 1 reports the information on farmers' willingness to adopt different CLP techniques. Approximately 86.7% of the farmers in the sample area were willing to adopt these techniques, and most farmers adopted two or more types of CLP techniques, with the proportions of straw incorporation, organic fertilizer application, farmyard manure and deep pine farmland being 90.0%, 20.7%, 21.1% and 20.4%, respectively. To eliminate the burning of crop straw, China has implemented a strict prohibition policy on the practices. The substitution of organic fertilizer application for chemical fertilizer is one of the most important types of CLP techniques. The long-term excessive application of chemical fertilizer aggravates cultivated land pollution and results in a decline in agricultural product quality. Therefore, the Chinese government has proposed the goal of "zero growth in chemical fertilizer use," and it has vigorously promoted the substitution of organic fertilizer application for chemical fertilizer application. Organic farming started in the 1990 in China. In 2003, the State Council of the PRC issued the document "the Certification and Accreditation Ordinance." This policy promoted the development of organic farming in China. Currently, the planting area of organic farming in China is about 2.27 million hectares, accounting for only 1.89 percent of its total cultivated land area [26].

In recent years, farmland transfer in China has experienced rapid development. The trend of scale management of farmland in agricultural production is accelerating, and the differences in the cultivated land endowment between farmers are prominent. To quantitatively compare FBACT between farmers with different farmland sizes, this paper defines farmers with farmland sizes larger than the mean farmland size of local county farmers as large-scale farmers; otherwise, they are small-scale farmers. The proportions of large-scale farmers and small-scale farmers in the sample area were 22.2% and 77.8%, respectively. Except for farmyard manure application, the proportions of straw incorporation, organic fertilizer application and deep pine farmland used by large-scale farmers were significantly higher than those of small-scale farmers. Large-scale farmers pay more attention to the long-term benefits from agricultural production, and their probability of adopting CLP techniques will be higher.

The willingness of farmers inflowing land to adopt CLP techniques was lower than that of farmers not inflowing land (including farmers outflowing land and farmers who have not participated in farmland transfer). In China, the farmland transfer contracts between farmers are mainly informal, and they are more inclined to pursue yield stability and risk avoidance. Thus, the probability of adopting CLP techniques will decline. However, the probability of farmers inflowing land adopting the four CLP techniques was significantly higher than

TABLE 1 | Proportion of farmers choosing CLR (%).

Variables	Definition	Full sample	Proportion			
			Large-scale farmers	Small-scale farmers	Farmers inflowing land	Farmers not inflowing land
Farmers' willingness to adopt CLP techniques	0 = no, 1 = yes	0.867	0.867	0.867	0.864	0.872
Farmyard manure	0 = no, 1 = yes	0.211	0.167	0.224	0.244	0.149
Straw incorporation	0 = no, 1 = yes	0.900	0.950	0.886	0.903	0.894
Organic fertilizer application	0 = no, 1 = yes	0.207	0.233	0.200	0.227	0.170
Deep pine farmland	0 = no, 1 = yes	0.204	0.283	0.181	0.233	0.149
Sample size		270	60	210	176	94

Note: (1) Author calculated based on the survey data. (2) The same farmer may choose multiple CLR measures, and the sum of the four different recuperation measure proportions is not necessarily equal to 1.

TABLE 2 | Descriptive statistics of each variable.

Variables	Definition	Mean	Std. Dev
Farmland size (ha)	Hectare	4.26	6.97
Number of plots	Pieces	3.55	2.25
Reciprocal of plot size	Pieces/hectare	5.50	7.22
Distance from the plot to the home	1 = near, 2 = middle, 3 = far	1.86	0.72
Certification of farmland rights	0 = no, 1 = yes	0.33	0.47
Area of transfer-in land	Hectare	5.62	7.25
Source of transfer-in land	0 = local village, 1 = other villages	0.20	0.40
Effect of CLP on yield	0 = negative, 1 = no effect, 2 = positive	1.58	0.64
Effect of CLP on product quality	Same as above	1.53	0.78
Effect of CLP on production costs	Same as above	1.07	0.95
Age	Year	58.09	10.74
Education	Year	8.14	3.61
Distribution of family labor	1 = farming, 2 = mainly farming, 3 = less farming, 4 = not farming	1.63	0.90
Leader at the village level in the family	0 = no, 1 = yes	0.33	0.47
Number of agricultural laborers	Number	2.03	0.80
Agricultural labor price	Yuan/day	118.08	34.34
Number of farming years	Year	27.21	14.79
Farmland quality	1 = poor, 2 = middle, 3 = fertile	2.43	0.61

Note: (1) Author calculated based on the survey data.

that of farmers not inflowing land. There were differences in CLP techniques adoption willingness and behavior among farmers not inflowing land. The reason may be that these farmers may not carry out agricultural production or that their agriculture is mainly for self-sufficiency. The proportion of these farmers adopting CLP techniques will be relatively low under a situation of high agricultural costs and low incomes.

Table 2 shows the descriptive statistics of each variable. The area of transfer-in land was 5.62 ha, and 20% of the transfer-in land came from outside the village. The number of plots in the sample area was 3.55, and each hectare of farmland was divided into 5.50. The distance of plots from the home was within the acceptable range. Farmers generally believed that CLP could improve the yield and agricultural product quality, and thus increase production costs. Most farmers believed that the quality of cultivated land was good. The mean number of agricultural laborers in a family was 2.03, the mean age of farmers was 58.09 years, the mean number of farming years was 27.21, and the mean number of years of education was 8.14. China's agricultural production has shown aging and part-time worker employment.

RESULTS

Impact of Farmland Transfer on Farmers' Willingness to Adopt CLP

Stata 15.0 (Stata Corp LLC, College Station, TX, United States) software was used to quantitatively estimate the impact of farmland transfer on farmers' willingness to adopt CLP techniques (**Table 3**). The Wald statistics of Model 1 and Model 2 are both significant at the 1% level, and the model estimation results are good. Model 2 provides the result of adding the farmland transfer variables on the basis of Model 1 to examine the impact of farmland transfer on farmers' willingness to adopt CLP techniques under land fragmentation. The following results are based on Model 2.

The expansion of the inflowing land area increases farmers' willingness to adopt CLP techniques. Farmers who expand their farmland size by inflowing land have abundant capital endowments, and they are also more sensitive to the future benefits from agriculture (Lu et al., 2019b). Agricultural policy in China will gradually shift from the pursuit of increased yields to the

TABLE 3 | Impact of farmland transfer on farmers' willingness to adopt CLR.

Variables	Model 1		Model 2	
	Probit	dy/dx	Probit	dy/dx
Farmland size	0.0004	0.0001	−0.0211**	−0.0015**
	(0.0013)	(0.0002)	(0.0101)	(0.0006)
Number of plots	−0.0185	−0.0030	−0.5329**	−0.0367**
	(0.0608)	(0.0010)	(0.2281)	(0.0146)
Reciprocal of plot size	−0.2232	−0.0363	−16.2361	−0.8423*
	(0.1872)	(0.0302)	(11.2477)	(0.4671)
Distance from the plot to the home	−0.1994	−0.0325	−0.4851*	−0.0213**
	(0.1640)	(0.0264)	(0.2882)	(0.0101)
Certification of farmland rights	0.4864	0.0791	0.4534	0.0312
	(0.3119)	(0.0506)	(0.5797)	(0.0402)
Area of transfer-in land	--	--	0.0266**	0.0018***
			(0.0108)	(0.0007)
Source of transfer-in land	--	--	−1.7070***	−0.1176***
			(0.5873)	(0.0394)
Effect of CLP on yield	0.6607***	0.1075***	1.1292***	0.0778
	(0.1570)	(0.0245)	(0.3238)	(0.0184)
Effect of CLP on product quality	0.2840*	0.0462**	1.0817***	0.0745***
	(0.1461)	(0.0234)	(0.3287)	(0.0219)
Effect of CLP on production cost	−0.3343**	−0.0544***	−0.8644**	−0.0596**
	(0.1322)	(0.0208)	(0.3848)	(0.0248)
Age	−0.0293*	−0.0048*	−0.1608***	−0.0111***
	(0.0157)	(0.0026)	(0.0410)	(0.0023)
Education	0.0242	0.0039	0.4611**	0.0118***
	(0.0307)	(0.0050)	(0.2063)	(0.0117)
Distribution of family labor	−0.1087	−0.0177	−1.1510**	−0.0793***
	(0.1324)	(0.0215)	(0.4687)	(0.0278)
Leader at the village level in family	0.1217	0.0198	1.8933**	0.1305***
	(0.2329)	(0.0377)	(0.7512)	(0.0435)
Number of agricultural laborers	0.1203	0.0196	1.3180***	0.0908***
	(0.1695)	(0.0272)	(0.4953)	(0.0286)
Agricultural labor price	−0.0082**	−0.0013**	−0.0089	−0.0006
	(0.0037)	(0.0006)	(0.0061)	(0.0005)
Number of farming years	0.0140	0.0023	0.0295	0.0020
	(0.0093)	(0.0015)	(0.0237)	(0.0015)
Farmland land quality	0.3212*	0.0523*	1.3039**	0.0899**
	(0.1729)	(0.0268)	(0.5311)	(0.0359)
Region	control	control	control	control
Constant term	2.0828	--	12.2706***	--
	(1.3762)		(3.3240)	
Wald chi^2	51.78***	--	41.84***	--
Likelihood	−79.60		−14.71	

*Note: (1) ***, ** and* indicate significance at the 1%, 5%, and 10% levels, respectively. (2) Robust standard errors are given in parentheses.*

pursuit of higher-quality products that meet consumer' demand and maximize long-term agricultural benefits. Inflowing land from outside the village reduces farmers' CLP technique adoption willingness. In China, farmers pay more attention to benefits and investment risks when making decisions regarding transfer-in land, and they are more likely to adopt protection techniques on their own land or local village land. The number of plots, reciprocal of plot size and distance from the plot to the home are significant. The results show that land fragmentation reduces the willingness of farmers to adopt CLP techniques. Land fragmentation not only uses more time when a machine changes direction but also slows down the speed and efficiency of machinery. Due to increased boundaries and ridges between small and dispersed plots, irrigation efficiency falls, and agricultural operation time is wasted, leading to poor field management. As a result, the factor input cost of CLP will increase and the farmers' willingness to adopt CLP techniques declined.

The effect of CLP on yield and effect of CLP on product quality have a significant positive impact on farmers' willingness to adopt CLP techniques, while the effect of CLP on production cost has a significant negative impact. The willingness of farmers to adopt protection techniques is affected by the cost of such techniques and farmers' expectations of benefits. An increase in the expectation of benefits will promote their willingness to adopt CLP techniques. The impact of farmland size on farmers' willingness to adopt CLP techniques is significantly negative, which is inconsistent with most existing conclusions. The reason may be that an increase in farmland size does not imply an increase in plot size. That is, an increase in farmland size may increase the number of plots and, consequently, increase the cost

TABLE 4 | Results of the multivariate probit regression covariance matrix.

CLP techniques	Crop straw incorporation	Farmyard manure application	Organic fertilizer application	Deep pine farmland
Crop straw incorporation	1	--	--	--
Farmyard manure application	-0.575***	1	--	--
Organic fertilizer application	0.098**	0.132	1	--
Deep pine farmland	-0.189	-0.004	0.094	1
Likelihood ratio test	rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0 chi2 = 4.796***			

*Note: (1) ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.*

of CLP and reduce the willingness of farmers to adopt CLP techniques.

The effect of education on farmers' willingness to adopt CLP techniques is positive. Improving education is helpful in enhancing farmers' cognition of CLP and promoting techniques adoption. Age has a significantly negative impact on farmers' willingness to adopt CLP techniques, and older farmers rely more on agricultural experience. In China, leaders at the village level play a major role in demonstrating and supervising the promotion of CLP policy. The number of agricultural laborers has a significantly positive impact. Notably, farmers have a higher willingness to adopt CLP techniques when they believe that cultivated land is currently of better quality, and the better cultivated land quality will motivate farmers to adopt protection techniques.

Effect of Farmland Transfer on FBACT

Theoretically, there is a complementary relationship between the different CLP techniques. Organic fertilizer application and crop straw incorporation require more money, while farmyard manure application and deep pine farmland require much more labor in China. This study further analyzed the impact of farmland transfer on FBACT and analyzed the differences. The multivariate probit regression covariance matrix is shown in **Table 4**. The Wald chi2 value is significant at the 1% level, indicating that there is a substitution effect between crop straw incorporation and farmyard manure application, as well as a complementary effect with organic fertilizer application.

Table 5 reports the results of the impact of farmland transfer on FBACT. The source of inflowing land has an important influence on FBACT. Transferring in land (land transferred from farmers of the same village encourages farmers to adopt organic fertilizer and deep pine farmland. Although this effect on crop straw incorporation and farmyard manure application is not significant, the negative coefficient also indicates that inflowing land from outside the village reduces FBACT. To reduce the investment risk, farmers are more inclined to protect farmland on the land of local village. Crop straw incorporation and organic fertilizer application can improve soil fertility and product quality, and the market demand for high-quality agricultural products is increasing. Farmers are more likely to adopt these techniques if they have a higher cognitive awareness of the fact that crop straw incorporation and organic fertilizer application can improve the quality of agricultural products. Farmyard manure mainly comes from the manure of poultry raised by farmers, and it requires a large labor force to transport it to farmland for application. In China, the decrease in the agricultural labor force and the rapid rise in labor prices will limit the use of farmyard manure. The impact of area of transfer-in land on farmers' adoption of deep pine farmland is significantly negative at the 10% level, and it has no effect on crop straw incorporation, organic fertilizer application and farmyard manure application. Although large areas of transfer-in land encourage FBACT, in reality, there is often a contradiction between farmers' CLP technique adoption willingness and behavior.

Land fragmentation has a significant impact on FBACT. The deepening of the reciprocal of plot size reduces the probability of farmers to incorporating crop straw and applying farmyard manure and organic fertilizer. It is necessary to apply agricultural machinery to incorporate crop straw, and the cost of agricultural machinery application will be seriously affected by land fragmentation. An increase in the number of plots will reduce the probability of FBACT, as the farther the distance from the plot to the home is, the lower the probability of farmers having deep pine farmland.

DISCUSSION

The Chinese government is vigorously implementing a rural revitalization strategy and promoting the development of green agriculture. Farmers are the most important participants, and the difference in farmland endowments among farmers should not be ignored. Large-scale farmers will be the main force adopting CLP techniques in the future. However, most of the proportion of large-scale farmers in China are generated through farmland transfer, and many of them are from outside villages. To promote the adoption of CLP techniques, farmers should be further encouraged to transfer-in land from within their village. Transfer-in land from within the village is basically derived from relatives working outside the village. Thus, compared with the transfer-in land outside their village, farmers have a more stable expectation of land use rights and a lower investment risk. In addition, most farmland transfers between farmers are based on informal oral contracts, and the increased investment risk of transferred farmers hinders their adoption of CLP techniques due to unstable land use rights. In

TABLE 5 | Impact of farmland transfer on farmers' adoption of CLP techniques.

Variables	Dependent variable			
	Farmyard manure application	Crop straw incorporation	Organic fertilizer application	Deep pine farmland
Farmland size	0.000	0.002	−0.003	0.011*
	(0.004)	(0.003)	(0.004)	(0.006)
Number of plots	−0.017	−0.160*	−0.021	−0.054
	(0.078)	(0.084)	(0.067)	(0.072)
Reciprocal of plot size	−0.535**	−0.190**	−0.370*	−0.200
	(0.243)	(0.079)	(0.197)	(0.210)
Distance from the plot to the home	0.944	1.495	−2.327	−3.156*
	(0.920)	(1.461)	(1.545)	(1.630)
Certification of farmland rights	0.775**	−0.389	−0.176	−0.012
	(0.389)	(0.493)	(0.334)	(0.332)
Area of transfer-in land	0.001	−0.001	0.002	−0.011*
	(0.004)	(0.003)	(0.003)	(0.006)
Source of transfer-in land	−0.507	v0.671	−0.008**	−0.765*
	(0.448)	(0.696)	(0.004)	(0.424)
Effect of CLP on yield	−0.124	0.073	0.324	0.205
	(0.292)	(0.305)	(0.282)	(0.241)
Effect of CLP on product quality	0.014	0.545**	0.465**	0.256
	(0.256)	(0.262)	(0.227)	(0.227)
Effect of CLP on production cost	0.133	−0.289*	−0.005	−0.047
	(0.191)	(0.168)	(0.147)	(0.148)
Age	−0.025	−0.004	−0.001	−0.001
	(0.017)	(0.020)	(0.015)	(0.017)
Education	0.159***	−0.009	0.031	0.062
	(0.061)	(0.047)	(0.041)	(0.055)
Distribution of family labor	−0.006	−0.096	−0.130	0.240
	(0.211)	(0.270)	(0.145)	(0.172)
Leader at the village level in family	−0.006	−0.006	−0.001	−0.007
	(0.006)	(0.012)	(0.004)	(0.005)
Number of agricultural laborers	0.024*	−0.005	−0.003	−0.009
	(0.013)	(0.011)	(0.011)	(0.011)
Agricultural labor price	−0.467*	−0.009	−0.013	−0.276
	(0.278)	(0.394)	(0.244)	(0.244)
Number of farming years	0.421	0.084	0.276	0.148
	(0.257)	(0.291)	(0.247)	(0.262)
Farmland land quality	−2.011	−0.199	−0.486	−1.429
	(1.501)	(2.587)	(1.342)	(1.468)
Region		257.59***		
Constant term		−191.08		

*Note: (1) ***, ** and* indicate significance at the 1%, 5%, and 10% levels, respectively. (2) Robust standard errors are given in parentheses.*

addition, based on the separation of the three rights of farmland, it is necessary to establish a well-functioning farmland transfer mechanism and market to provide farmland transfer. The government should standardize contracts for farmland transfer and strengthen its supervision of the farmland transfer market, thus increasing the stability of land use rights. Measures that facilitate rural labor transfer to nonfarming jobs in cities should be implemented. The urban welfare system should be extended to cover all residents, and provide them with the same benefits and treatment to enhance migrant workers' sense of belonging in cities. Optimizing institutional arrangements with respect to nonagricultural employment and rural social security will be conducive to increasing farmers' enthusiasm for farmland transfer.

Although farmland transfer market is developing well, China will still engage in agriculture on fragmented land. Many CLP techniques need to be applied on larger plot sizes to be efficient and inexpensive. In the future, small-scale farmers will still be the main participants in agricultural production in China. The rapid development of farmland transfer in China has become an important way to compensate for the negative effects of small-scale farmers on agricultural production. Policies that support the construction of agricultural infrastructure, such as road protection and water irrigation, will guide small-scale farmers to take collective actions in agricultural production, and striving to realize the centralized and contiguous operation of scattered farmland can alleviate the inhibitory effect of land fragmentation on the use of agricultural machinery. The government should strongly encourage farmers to integrate and exchange adjacent plots on a voluntary basis.

In China, agricultural policy is also shifting from increasing yield to improving the quality of agricultural products. In 2021, the Ministry of Agriculture and Rural Affairs of the People's Republic of China released the "National Agricultural Green

Development Plan during the 14th Five-Year Plan period" and has been dedicated to "Move faster to shift agriculture from increasing production to improving quality, and better meet the multilevel and individualized consumer needs of urban and rural residents." The consumption structure of residents is increasingly being upgraded, and the market demand for high-quality agricultural products is also increasing. The expectation of benefits from CLP has a significant impact on farmers' adoption of CLP techniques. The government should make full use of the relationship between farmers' expectations of CLP benefit and their willingness to adopt CLP techniques. It should further strengthen publicity and training related to CLP techniques, develop relevant preferential incentives to guide large-scale farmers to adopt CLP techniques, increase their subjective initiative and stabilize their expectations.

CONCLUSION

This paper analyzed the impact of farmland transfer on FBACT based on field research and questionnaire surveys conducted in Jiangsu Province, China. The conclusion are as follows. First, many farmers choose to participate in farmland transfer. The area of contracted land participating in farmland transfer has been increasing. The probability of farmers with transfer-in land adopting the four CLP techniques is significantly higher than that of farmers not transfer-in land. Second, farmland transfer in China promotes FBACT, and the source of transfer-in land has an important influence on FBACT. Transfer-in land from within the village will encourage farmers to adopt organic fertilizer and deep pine farmland. Large areas of transfer-in land increase the willingness of farmers to adopt CLP techniques. Second, land fragmentation reduces farmers' willingness to adopt such techniques. The deepening of the reciprocal of plot size reduces the probability of farmers incorporating crop straw, and applying farmyard manure and organic fertilizer. An increase in the number of plots will reduce the probability of farmers incorporating crop straw. Third, the expectation of improved product quality due to CLP increases the probability of farmers adopting organic fertilizers and crop straw incorporation. However, the expectation of increased cost reduces the probability of farmers adopting organic fertilizer. Finally, the willingness of farmers to adopt CLP techniques is also affected by their age, their education, family labor and agricultural labor prices.

RECOMMENDATIONS

Increasing the adoption rate of CLP techniques requires the support of government policies and the active cooperation of farmers. Any agricultural policy that does not respect the wishes of farmers will not be implemented successfully and cost-effectively. Therefore, an education and training program should be developed, and efforts should be made to publicize the positive effects of CLP on increasing the yield and quality of agricultural products. The goal is to impress upon farmers that the government is helping them carry out the transformation to a healthy and environmentally friendly lifestyle in rural areas. Moreover, measures should be taken to enhance farmers' cognition of CLP techniques and increase their willingness to adopt. In such a way they become the direct beneficiaries of those techniques. For CLP techniques with inconsistent input and output times, it is very important to make great efforts to publicize the positive effects of CLP on the expected stability of yields and improvement in agricultural product quality. Information about CLP techniques provided by natural science also has an important impact on the perception and willingness of farmers to adopt them.

In China, land fragmentation has not fundamentally changed, and in fact it has shown a worsening trend. The protection of cultivated land quality requires a certain scale of contiguous land area as the basis, and the transfer of adjacent plots between farmers should be strongly encouraged to expand the plot area and reduce the cost of the protection of cultivated land quality in a single plot. In addition, agricultural policy strongly supports the development of socialized agricultural service organizations in China. Such organizations have comparative advantages in the utilization of modern agricultural production factors, such as capital, modern production technology and managerial skills, and they have become an important way to offset the negative impact of agricultural labor shortages and small-scale land management on land use. The protection of cultivated land quality can be promoted by optimizing the allocation of agricultural production factors. It is also necessary to regulate the behavior of these types of organizations and to improve their service quality and service standardization. Land endowments, benefit expectations and the ability to respond to market changes are different for different farmers. To promote their adoption of CLP techniques, attention should be paid to the differences between farmers with different farmland sizes to ultimately reduce adoption costs and prevent moral hazard. Additionally, based on the experiences of other countries, enterprises in China should be encouraged to assist farmers in implementing CLP at a low price instead of expecting farmers to do so all on their own.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

HL had the original idea and data collecting, YC, HH, and ND carried out the analyses for the study, the authors drafted the manuscript and the approved the manuscript.

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