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Effects of participation in cooperatives on the cultivated land quality protection behavior of grain family farms: evidence from China

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Introduction: The implementation of cultivated land quality protection is fundamental for ensuring the sustainable use of land resources, and it is the inevitable choice for maintaining the balance of agricultural ecology and promoting the long-term healthy development of agriculture.

Methods: Based on survey data from 927 grain family farms in 13 major grain-producing areas in China, this paper empirically tests the effects of participation in cooperatives on the cultivated land quality protection behavior of grain family farms by using a logit model, an ordered probit model and the propensity score matching method.

Results: The results show that participation in cooperatives has a significant positive effect on the implementation of cultivated land quality protection behavior and the degree of cultivated land quality protection of grain family farms. A series of robustness tests reveals that the conclusion of the study does not change. Heterogeneity analysis reveals that the probability of implementing cultivated land quality protection behavior significantly increased, and the effect was greater for farms with the younger farmers, farmers of lower education level, farmers of non-party members, larger scale of operation, longer establishment years, larger labor force, or provincial demonstration.

Discussion: On this basis, we should vigorously support and guide grain family farms to participate in cooperatives, give full play to the advantages of cooperatives, effectively encourage farms to implement cultivated land quality protection behavior, and promote sustainable agricultural development.

KEYWORDS

participation in cooperatives, grain family farms, cultivated land quality protection behavior, effects, China

1 Introduction

Cultivated land is not only the basis of agricultural production but also the lifeblood of the human food supply (Su et al., 2023). Protecting the quality of cultivated land is an inevitable requirement for ensuring global food security, ecological balance, social stability and reducing the adverse effects of climate change (Li and Li, 2019). The implementation of cultivated land quality protection is conducive to maintaining soil health, improving farmland productivity, increasing food output, and promoting sustainable agricultural development (Mo et al., 2023). Therefore, it is necessary to actively guide and support grain family farms to comply with the principles of cultivated land quality protection, and to strengthen green long-term mechanism construction for cultivated land quality protection, so as to achieve food supply security.

Compared with foreign developed countries, there is still a certain gap in the intensity of cultivated land quality protection in China, and the speed and efficiency of cultivated land quality protection need to be improved (Li et al., 2017). The reason is that agricultural production in China still relies mainly on small-scale scattered management and traditional farming methods, which can easily damage the soil structure, increase the risk of soil erosion and accelerate land degradation. Additionally, agricultural production has a low degree of organization, which makes it difficult to implement large-scale farming management for scientific and rational utilization of land resources. The high cost and risk of small farmers' implementation of cultivated land quality protection behavior, coupled with the low level of agricultural land quality protection promotion and the low quality of participants, lead to the slow progress in agricultural land quality protection promotion in China (Feng et al., 2023). As a new agricultural management entity, grain family farms have a certain scale effect (Yu et al., 2020) and are more inclined to implement land quality protection behavior than small farmers are. However, according to the authors' investigations, compared with cooperatives, grain family farms do not have a high degree of cultivated land quality protection. Therefore, it is necessary for these farms to cooperate with other new agricultural management entities, such as cooperatives. Research shows that cooperatives can not only share advanced agricultural technology and management experience (Jiang, 2001), improve the level of scientific management of cultivated land and enhance the effectiveness of cultivated land quality protection (Zhao et al., 2021) but also give full play to the advantages of scale, increase the effectiveness of cost sharing and promote the process of land quality protection (Xu W. Y. et al., 2023). Therefore, the "grain family farm + cooperative" model, which is based on grain family farms, could be a feasible way to solve the problem of promoting agricultural cultivated land quality protection in China.

2 Literature review and theoretical analysis

2.1 Literature review

Research on cultivated land quality protection behavior in China and elsewhere has focused mainly on two aspects. The first is the policy, cognition and willingness to implement cultivated land quality protection, and the second is the influencing factors of cultivated land quality protection behavior.

Cultivated land quality protection behavior refers to a series of measures taken to protect and improve the quality of cultivated land and maintain the sustainable development of agriculture through scientific and reasonable agricultural production management, land use planning and environmental monitoring. Many scholars have studied policies and regulations for the implementation of cultivated land quality protection. For example, Wei et al. used the methods of data analysis and qualitative description to divide cultivated land protection policies into five stages according to the connotation of cultivated land protection policy. They ascertained the difference in the quantity and quality protection effect of cultivated land protection policy based on the two scales of time and space. Finally they proposed the direction and trend of future policy introduction (Wei et al., 2023). Wang et al. (2023) argued that the government has certain defects in cultivated land protection policy, and it is necessary to reestablish the top-level design of cultivated land quality protection according to the three-dimensional composite system of "economic incentives, policy regulation and ecological governance"; implement strict cultivated land quality control and an orderly management mechanism for cultivated land quality; and formulate corresponding strategies to address the continuous weakening of cultivated land quality to ensure national food security. Based on policy regulations, scholars have conducted in-depth research on the degree of cognition and behavioral willingness of farmers toward the implementation of cultivated land quality protection. For example, Xu et al. used a farmer questionnaire and binary logistic regression model. They used whether farmers think that it is necessary to implement cultivated land quality protection policies as the dependent variable and 13 variables reflecting farmers' characteristics, farming conditions, cultivated land cognition and attitudes toward cultivated land quality protection as the independent variables to analyze whether farmers think that it is necessary to implement cultivated land protection and its influencing factors (Xu T. et al., 2023).

Research on the influencing factors of cultivated land quality protection behavior has taken two main perspectives,

TABLE 1 Factors influencing cultivated land quality protection behavior.

Category	Factors	References
1. Personal characteristics	Farmers' co-employment	Schmid et al., 2013
	Farmers' cognition	Guo et al., 2022
	Environmental emotion	Cai et al., 2023
	Farmers' capital endowment	Li et al., 2021
	Farmers' land awareness differentiation	Schröder et al., 2020
2. Policy regulation	Fallow policy	Xie and Wu, 2020
	Farmland ownership confirmation	Guan et al., 2022
	Farmland transfer system	Li and Zhang, 2021
	Agricultural subsidy policy	Bai et al., 2022
3. Production characteristic	Planting scale and fragmentation	Avon et al., 2015
	Technology adoption	Feyisa, 2020
	Agricultural productive service	Shi et al., 2024
4. Market behavior	Agricultural socialization service	Qiu et al., 2023
	E-commerce participation	Yi et al., 2023
	Full cost insurance	Zhong et al., 2023

farmer households and family farms, and research results from the perspective of family farms are relatively rare. From the perspective of farmers' household, based on the relevant literature, some factors of different categories have significant impact on farmers' implementation of cultivated land quality protection behavior which is presented below in Table 1.

From the perspective of family farms, based on a small number of existing research results, research has focused on the impact of land rights stability on the cultivated land quality protection behavior of family farms. For example, Ma et al. (2023) used a spatial econometric model to analyze the impact of contract stability on the cultivated land quality protection behavior of family farms based on field survey data from 567 planting family farms in Jinhu County, Jiangsu Province, in 2018, and they tested the demonstration effect of cultivated land quality protection behavior among family farms. Using 312 planting family farms in Shandong Province as micro-samples, Li et al. (2023) used binary probit regression to empirically test the influence of the stability of land management rights on the cultivated land protection behavior of family farms, and they tested the robustness of the research conclusions via mvprobit regression.

In summary, although there are considerable research results on cultivated land quality protection behavior and its influencing factors in China and elsewhere, research on the relationship between participation in cooperatives and the cultivated land quality protection behavior of grain family farms is lacking. However, family farms are an important pillar for ensuring food security, and their cultivated land quality protection behavior is necessary for maintaining the health of soil ecosystems and ensuring ecological balance and agricultural sustainability. By participating in cooperatives, grain family farms can strengthen their cooperation in agricultural production, promote resource sharing and technological innovation, enhance the willingness and ability to implement cultivated land quality protection behavior, and improve the quality and quantity of agricultural products, thus realizing steady growth in farmers' income and the sustainability of agricultural production. On this basis, this article empirically analyses the effects of participation in cooperatives on the cultivated land quality protection behavior and protection degree of grain family farms by using 927 survey data points from grain family farms. This article attempts to answer the following questions. Does participation in cooperatives have an impact on the implementation and the degree of cultivated land quality protection of grain family farms? If so, to what extent? Is there inter-group heterogeneity in the effects of participation in cooperatives on the cultivated land quality protection behavior of grain family farms?

2.2 Theoretical analysis

Schulz's "rational smallholder" hypothesis holds that farmers' production goal is profit maximization and that farmers will use the expected net income and risk loss of the scheme as the judgement criteria when facing several scheme choices. Based on the research of Zhao et al. (2023), the theoretical framework of this article is established as follows.

$$f = \pi_h - \pi_l = (p_h \times y_h - \sum_{i=1}^{m} r_{hi} \times x_{hi} - v_h) - (p_l - y_l - \sum_{i=1}^{m} r_{li} \times x_{li} - v_l) \quad (1)$$

In Equation (1), π_h and π_l refer to the net operating income obtained from the implementation of a high degree of cultivated land quality protection and a low degree of cultivated land quality protection respectively, and f is the difference in the net operating income of the two; p_h and p_l and y_h and y_l represent the grain price and grain output respectively under different degrees of cultivated land quality protection behavior; r_{hi} and r_{li} and x_{hi} and x_{li} refer to the factor input price and input quantity respectively under different degrees of cultivated land quality protection behavior; v_h and v_l refer to operational risk losses under different degrees of cultivated land quality protection behavior, $v_h > v_l$. i represents input factors such as seeds and technology. When $f > 0$, rational grain family farms choose to implement a high degree of cultivated land quality protection behavior; conversely, they choose to implement a low degree of cultivated land quality protection behavior.

It is assumed that the same amount of participation in cooperatives is added to the high and low degrees of cultivated land quality protection behavior, and the input of participation in cooperatives has no additional differentiated impact on grain output and price. The operating net profit function for a high degree or a low degree of cultivated land quality protection behavior is constructed after introducing participation in cooperatives.

$$\begin{aligned} f(s) &= \pi_h(s) - \pi_l(s) \\ &= [p_h \times y_h - \textstyle\sum_{i=1}^{m} r_{hi}(s) \times x_{hi}(s) - v_h(s) - c(s)] - \\ &[p_l \times y_l - \textstyle\sum_{i=1}^{m} r_{li}(s) \times x_{li}(s) - v_l(s) - c(s)] \end{aligned} \quad (2)$$

In Equation (2), $c(s)$ is the cost of participating in a cooperative, and the other symbols have the same meaning as in Equation (1) or are the value of each index after participating in a cooperative. When $f(s) > 0$, grain family farms will implement a high degree of cultivated land quality protection behavior; conversely, they will implement a low degree of cultivated land quality protection behavior. To analyze the difference in the production behavior decision-making of grain family farms after participating in cooperatives, it is necessary to construct the following equation.

$$\begin{aligned} g = f(s) - f &= [r_l(s) \times x_l(s) - r_l \times x_l] \\ &-[r_h(s) \times x_h(s) - r_h \times x_h] + [v_h - v_h(s)] - [v_l - v_l(s)] \end{aligned} \quad (3)$$

In Equation (3), g is the difference in the net income of different degrees of cultivated land quality protection behavior according to whether grain family farms participate in a cooperative. When $g > 0$, grain family farms participating in cooperatives will promote their implementation of a high degree of cultivated land quality protection behavior; conversely, the probability of implementing a high degree of cultivated land quality protection behavior will decrease.

Cooperatives provide effective resource sharing and management mechanisms, optimize resource allocation through collaborative cooperation, and reduce the probability of factor overuse to a certain extent (Teng et al., 2022). Specifically, first, cooperatives can achieve economies of scale and reduce production costs by centralizing purchases, production and sales (Hoken and Su, 2018). Second, cooperatives can provide technical support and training to improve members' production skills and management level, thereby improving production efficiency (Wang and Wang, 2019). Moreover, cooperatives promote information sharing and collaborative work among members to avoid information asymmetry and resource waste (Yu et al., 2022). In addition, cooperatives make full use of resources and avoid redundant investment by co-owning agricultural equipment and infrastructure (El Fartassi et al., 2023). Finally, the organizational structure of cooperatives can reduce competition among individual members, formulate rational production plans, and prevent the overexploitation of land and overuse of agricultural elements (Pombo-Romero et al., 2023). Therefore, after a family farm participates in a cooperative, the factor input and price associated with a low degree of cultivated land quality protection behavior are higher than those associated with a high degree of cultivated land quality protection behavior, namely $[r_l(s) \times x_l(s) - r_l \times x_l] > [r_h(s) \times x_h(s) - r_h \times x_h]$.

There are economic risks, technical and educational risks and market risks in the cultivated land quality protection behavior of grain family farms. Cooperatives can effectively reduce economic risks by reducing production costs through collective purchases and sales as well as economies of scale and by easing financial pressure through co-financing and credit support. Improving members' production skills through technical training and sharing best practices can mitigate technical and educational risks. Market risks can be reduced by providing market information and collective bargaining power to help members better cope with market volatility (Garnevska et al., 2011). Therefore, participation in cooperatives has a more significant effect on reducing the risk loss of a high degree of cultivated land quality protection behavior, which means $[v_h - v_h(s)] > [v_l - v_l(s)]$. It can be inferred that $g > 0$; that is, participation in cooperatives increases the probability of implementing a high degree of cultivated land quality protection behavior of grain family farms.

In summary, cooperatives not only effectively match production factor resources and reduce the factor input costs associated with a high degree of cultivated land quality protection behavior, but also reduce various risk losses associated with a high degree of cultivated land quality protection behavior and improve the promoting role of cultivated land quality protection behavior. Therefore, the first hypothesis is proposed.

H_1: Participation in cooperatives has a significant positive effect on the cultivated land quality protection behavior of grain family farms.

In addition, differences in the individual characteristics of farmers and the basic characteristics of farms may lead to heterogeneity in the effects of cooperative participation on cultivated land quality protection behavior. From the perspective of the individual characteristics of farmers, these individual characteristics usually include age, educational level, party membership and other factors, and these differences affect farmers' cognition and attitudes toward environmental issues. Age may be related to the difference between farmers' traditional experience and new ideas; educational level may affect farmers' acceptance of new technologies and sustainable agricultural practices; and party membership may affect farmers' attitudes toward government policies. From the perspective of the basic characteristics of farms, the basic characteristics of farms usually include factors such as the scale of operation, the years of establishment, the number of laborers and whether the farm is a demonstration farm. Differences in these factors may affect the differences in farms in terms of resource allocation, management level and technology application. Large-scale farms may have more resources and labor, and it is easier for them to adopt advanced agricultural technology and management measures and implement more comprehensive plans for cultivated land quality protection. Different years of establishment reflect the different management experiences and agricultural practices of farms, and newly established farms and old farms may have different attitudes toward cultivated land quality protection behavior, thus affecting the implementation of this behavior. The quantity of the labor force is directly related to the productivity and management ability of farms and has a direct impact on the enthusiasm and feasibility of participation in cooperatives, which in turn affects the adoption of cultivated land quality protection behavior. As models of agricultural techniques and management, demonstration farms may be more likely to lead and promote the adoption and spread of more innovative and sustainable cultivated land quality protection practices through their participation in cooperatives. Therefore, the second hypothesis is proposed.

H_2: There is heterogeneity in the effects of cooperative participation on the cultivated land quality protection behavior of grain family farms.

3 Materials and methods

3.1 Data source

The data in this article are based on a questionnaire survey that was conducted in 13 major grain-producing regions of China (Heilongjiang, Henan, Shandong, Sichuan, Jiangsu, Hebei, Jilin, Anhui, Hunan, Hubei, Inner Mongolia, Jiangxi, Liaoning). The protection of cultivated land quality in major grain-producing areas plays an important role in Chinese food security, sustainable agricultural development and the overall health of the ecological environment. First, the protection of cultivated land quality is one of the key factors for ensuring grain yield and quality. Major grain-producing areas bear great a responsibility for Chinese grain production, and the stability of and improvement in their cultivated land quality directly determine the level of agricultural production capacity. Protecting the quality of cultivated land and improving land fertility can more effectively support crop growth and increase yield per unit area, thus ensuring the sustainability of the country's food supply. Second, the protection of cultivated land quality is closely related to the sustainable development of agriculture. Agriculture in Chinese major grain-producing areas is the backbone of the local economy, and as the basis of agricultural production, the stability of the quality of land directly affects the sustainability of agriculture. By adopting effective cultivated land protection behavior, problems such as overdevelopment and land degradation can be avoided, the sustainable utilization of land resources can be maintained, a lasting production basis for agriculture can be provided, and the steady development of agriculture can be promoted. Finally, the protection of cultivated land quality plays an important role in protecting and improving the ecological environment. Chinese major grain-producing areas cover a vast area and involve diverse and complex ecosystems. By protecting the quality of cultivated land, land pollution and ecosystem damage can be reduced, and the balance and diversity of cultivated land ecosystems can be promoted. However, the participation of grain family farms, which are the basic unit of agricultural production in major grain-producing areas, in cooperatives may have a profound impact on the agroecological system of the whole region. Therefore, 13 major grain-producing areas in China should be selected to explore the influence of participation in cooperatives of grain family farms on cultivated land quality protection behavior.

A survey of the grain family farm sample was carried out from July to August 2023. On the basis of the preliminary investigation, considering the natural environment, economic status, the production level and other factors, a combination of a typical investigation and random sampling was adopted to carry out the formal investigation. In each province, two typical grain production cities (counties) were selected, 2–3 townships (towns) were randomly selected in each city (counties), and 3–4 villages were randomly selected in each township (towns). Questionnaires were randomly distributed according to the number of grain family farms in villages. A total of 1,000 questionnaires were distributed, and the effective number of questionnaires was 927, for an effective response rate of 92.7%. The contents of the questionnaires included the basic situation of the farmers, the basic characteristics of the farms, participation in cooperatives and cultivated land quality protection behavior.

3.2 Variable selection

1. Dependent variable. We set two dependent variables: the cultivated land quality protection behavior of grain family farms and the degree of cultivated land quality protection of grain family farms. In reference to the research results of Chen and Liu (2023), this article regards the implementation of traditional cultivated land leveling (general cultivated land quality protection), organic fertilizer application, soil testing and formula fertilization (green cultivated land quality protection) as the adoption of cultivated land quality protection behaviors by grain family farms. These two dependent variables are binary variables. If cultivated land quality protection behavior is implemented on a grain family farm, the value is 1. Otherwise, the value is 0. General cultivated land quality protection behavior was evaluated by the following questionnaire item: "Has general cultivated land leveling been implemented on the grain family farm?" The answer set was "Yes = 1, no = 0." To determine green cultivated quality protection behavior, the following question was used: "Has the family farm implemented green cultivated quality protection behavior such as organic fertilizer application, soil testing and formula fertilization?" The answer setting was "Yes = 1, no = 0." In addition, the cultivated land quality protection degree of grain family farms was divided into three levels: no cultivated land quality protection behavior; general cultivated land quality protection behavior, such as traditional cultivated land leveling; and green cultivated land quality protection behavior, such as organic fertilizer application, soil testing and formula fertilization; The answer setting was 0, 1, and 2, respectively.
2. Independent variable. The independent variable is participation in a cooperative. A grain family farm is assigned the value of 1 if it participates in cooperatives or 0 if it does not.
3. Control variables. Considering the factors affecting the cultivated land quality protection behavior of grain family farms (Steiman et al., 2020), two types of control variables are introduced: the first type is farmer's personal characteristics, including gender, age, educational level, party member status, village cadre status, and non-agricultural work experience. Serving as a party member or village cadre reflects farmers' social capital, including their social network, trust relationships and degree of cooperation. The second type is the basic characteristics of farms, including the type of operation, the scale of operation, the years of establishment, whether the farm is a provincial demonstration farm, the number of laborers, and whether there is a stable sales channel. The number of laborers reflects the organization and management ability of the farm labor force, as well as the division and cooperation of family members in the agricultural production activities of the farm.

The definitions of the variables and descriptive statistics are shown in Table 2. In general, 72.2% of the farms had implemented cultivated land quality protection behavior, among which 8.1% had implemented general cultivated land quality protection behavior and 64.1% had implemented green cultivated land quality protection behavior. Approximately 65% of the farms participated in cooperatives. In terms of personal characteristics, the average age of the farmers was between 26 and 55 years, and the educational level of farmers was mostly at the middle or high school level. A total of 35.6% of the farmers were party members, 45% were village cadres, and 63.4% had non-agricultural work experience. In terms of the basic characteristics of farms, most farms operated cereal crops and legumes; the scale of operation of most farms was 50–200 acres; and the establishment period was 1–5 years. A total of 58.6% of the farms were provincial demonstration farms. 3–4 people were involved in the labor force, and 19.4% of the farms had stable sales channels.

3.3 Model setting

Construction of the basic regression model (Kim et al., 2015)

$$Y_i = \alpha_0 + \alpha_1 M_i + \alpha_2 Z_i + \varepsilon_i \tag{4}$$

TABLE 2 Definitions of the variables and descriptive statistics.

Type of variables	Names of variables	Assignment	Mean (standard deviation)	Members ($n = 603$)	Non-Members ($n = 324$)	Interpolation (t test)
Dependent variable	Whether cultivated land quality protection behavior has been implemented	Yes = 1, no = 0	0.722 (0.448)	0.881	0.426	0.455***
	Whether general cultivated land quality protection behavior has been implemented	Yes = 1, no = 0	0.081 (0.273)	0.114	0.019	0.096***
	Whether green cultivated land quality protection has been implemented	Yes = 1, no = 0	0.641 (0.48)	0.766	0.407	0.359***
	Degree of cultivated land quality protection	No implementation = 0, general cultivated land quality protection = 1, green cultivated land quality protection = 2	2.362 (0.888)	2.647	1.833	0.813***
Argument	Whether a cooperative has been joined	Yes = 1, no = 0	0.650 (0.477)	1	0	1
Control variables	Gender	Male = 1, female = 0	0.644 (0.479)	0.682	0.574	0.108***
	Age	<25 = 1; 26–40 = 2; 41–55 = 3; 56–70 = 4; 71 or older = 5	2.544 (0.765)	2.607	2.426	0.181***
	Educational level	0 years = 1; 1–6 years = 2; 7–9 years = 3; 10 to 12 years = 4; >12	3.628 (1.019)	3.988	3.716	0.272***
	Party member or not	Yes = 1, no = 0	0.356 (0.479)	0.493	0.318	0.175***
	Village cadre or not	Yes = 1, no = 0	0.45(0.498)	0.421	0.262	0.159***
	Off-farm work experience	Yes = 1, no = 0	0.634 (0.482)	0.692	0.528	0.164***
	Type of operation	Cereal crop = 1; legumes = 2; potato and taro crops = 3	1.365 (0.666)	1.365	1.364	0.001
	Scale of operation	<50 acres = 1; 50–100 acres = 2; 100–200 acres = 3; 200–300 acres = 4; 300+acres = 5	2.181 (1.012)	2.534	2.216	0.318***
	Years of establishment	<1 year = 1; 1–3 years = 2; 3–5 years = 3	2.375 (0.818)	2.388	2.352	0.036
	Whether the farm is a provincial demonstration farm	Yes = 1, no = 0	0.586 (0.493)	0.726	0.324	0.402***
	Number of laborers	1–3 people = 1; 3–4 people = 2; 5+ people = 3	2.032 (0.741)	2.055	1.991	0.064
	Whether there is a stable sales channel	Yes = 1, no = 0	0.194 (0.396)	0.179	0.222	0.043

***Indicates statistically significant at 1% level.

In Equation (4), Y_i is the behavior and degree of cultivated land quality protection implemented by grain family farms, M_i indicates whether grain family farms participate in cooperatives, Z_i is the control variable that affects the behavior and degree of cultivated land quality protection implemented by grain family farms, α_i is the coefficient to be estimated and ε_i is a random error term.

Since the first dependent variable, whether to implement cultivated land quality protection behavior, is a binary choice variable, the logit model is used to estimate the impact of participation in cooperatives on the implementation of cultivated land quality protection behavior by grain family farms (Naganuma et al., 2019). The specific expression is as follows:

$$Y_i = \Pr(M_i = 1|Z_i) = \wedge(Z_i^{'}\beta) = \frac{exp(Z_i^{'}\beta)}{1 + exp(Z_i^{'}\beta)} \tag{5}$$

In Equation (5), Y_i is the behavior of cultivated land quality protection implemented by grain family farms. M_i indicates whether grain family farms participate in cooperatives. Z_i is the control variable that affects the behavior of cultivated land quality protection implemented by grain family farms. $\wedge$ is the cumulative distribution function of the Logit distribution. i is a sample increasing variable.

Since the second dependent variable is the degree of cultivated land quality protection, which is a discrete and ordered variable, an ordered probit model (Chiou et al., 2013) is constructed to estimate the impact of participating in cooperatives on the degree of cultivated land quality protection of grain family farms. The selection rules are as follows:

$$Y_i = \begin{cases} 1, if\ Y_i^* \le C_1 \\ 2, if\, C_1 < Y_i^* \le C_2 \\ 3, if\, C_2 < Y_i^* \end{cases} \tag{6}$$

In Equation (6), Y_i^* is the latent variable of the degree of cultivated land quality protection of grain family farms, which cannot be observed. Y_i is observable, with values of 1, 2 and 3. C_1 and C_2 are the coefficients to be estimated. If the distribution function of ε_i is a cumulative standard normal distribution function, X_i represents all explanatory variables, and an ordered probit model is obtained.

$$P(Y_i = 1) = \varphi(C_1 - X_i\beta) \tag{7}$$

$$P(Y_i = 2) = \varphi(C_2 - X_i\beta) - \varphi(C_1 - X_i\beta) \tag{8}$$

$$P(Y_i = 3) = 1 - \varphi(C_2 - X_i\beta) \tag{9}$$

In Equations (7–9), Y_i is the observable variable of the degree of cultivated land quality protection of grain family farms. P is probability. φ is Cumulative standard normal distribution function.

In the present study, two questions need to be considered. Firstly, participation in cooperatives of farms is affected by many internal and external factors and is a self-selection behavior, which may lead to deviation of results. Second, it is not possible to observe the implementation of cultivated land quality protection behavior of non-participating farms after joining in cooperatives, and it is faced with the problem of missing data. Therefore, the propensity score matching method (Langworthy et al., 2023) was used to test the robustness of the behavior and degree of cultivated land quality protection of grain family farms by participating in cooperatives. First, a logit or probit model was used to calculate the propensity score of the family farms that implemented cultivated land quality protection behavior. Second, according to the propensity score, family farms that participated in cooperatives and family farms that did not participate in cooperatives were matched. Finally, the average treatment effect ATT^{PSM} was calculated according to the propensity score. The calculation formula of ATT^{PSM} is shown as follows:

$$ATT^{PSM} = E\{E\left[Y_{1i}^{PSM}\,|M_i = 1, P(Z_i)\right] - E\left[Y_{0i}^{PSM}\,|M_i = 0, P(Z_i)\right]|M_i = 1\} \tag{10}$$

In Equation (10), if grain family farms participate in cooperatives, then $M_i = 1$; otherwise, $M_i = 0$. Z_i is the control variable for the individual characteristics of grain family farmers and the basic characteristics of grain family farms.

4 Results

4.1 Benchmark regression analysis

Stata 17.0 statistical software was used for estimation. Considering the possible multicollinearity among the explanatory variables, the variance inflation factor (VIF) was used to test the relevant explanatory variables (Ekiz, 2023). The maximum VIF of the explanatory variables is 1.55, the minimum value is 1.04, and the VIF is far less than 10, indicating that there is no serious multicollinearity among the relevant variables. Therefore, the selection of explanatory variables is reasonable.

In this paper, binary logit estimation and ordered probit estimation are used as benchmark regressions. The regression results are shown in Table 3, where Models 1, 2, and 3 are the results of binary logit estimation, and Model 4 is the results of ordered probit estimation. As shown in Model 1, Model 2, and Model 3, the coefficients of participation in cooperatives are all significantly positive at the 1% level, indicating that participation in cooperatives has a significant effect on the implementation of cultivated land quality protection behavior of grain family farms. According to the results of Model 4, there is a positive correlation between participation in cooperatives and the degree of cultivated land quality protection of grain family farms, and this correlation is significant at the 1% level, indicating that participation in cooperatives has a significant promoting effect on the degree of cultivated land quality protection of grain family farms. In terms of the control variables, the analysis and explanation were carried out mainly according to Model 1 (whether cultivated land quality protection behavior has been implemented). From the perspective of the individual characteristics of farmers, the coefficient of educational level is positive and significant at the 1% level, indicating that the higher the educational level of farmers is, the more inclined they are to implement cultivated land quality protection behavior. The reason may be that the

TABLE 3 Baseline regression results.

Variable names	Model 1 (whether implemented or not)	Model 2 (general cultivated land quality protection)	Model 3 (green cultivated land quality protection)	Model 4 (degree of cultivated land quality protection)
Whether a cooperative has been joined	2.222***	1.586***	1.278***	1.505***
	0.262	0.478	0.188	0.192
Gender	0.193	0.409	0.275	0.292
	0.246	0.337	0.18	0.178
Age	0.151	0.730***	0.491***	0.408***
	0.162	0.204	0.131	0.115
Educational level	1.628***	1.458***	0.419***	0.601***
	0.213	0.229	0.145	0.143
Party member or not	2.476***	0.382	1.560***	1.687***
	0.286	0.294	0.183	0.183
Village cadre or not	2.417***	0.007	1.371***	1.512***
	0.305	0.313	0.201	0.201
Non-farm work experience	0.537**	0.137	0.409**	0.426**
	0.242	0.312	0.176	0.177
Type of operation	0.407**	0.833***	0.558***	0.549***
	0.176	0.267	0.115	0.121
Scale of operation	1.211***	1.436***	0.138	0.294**
	0.183	0.229	0.128	0.121
Years of establishment	0.530***	0.272	0.364***	0.371***
	0.163	0.23	0.127	0.128
Whether the farm is a provincial demonstration farm	0.333	0.041	0.158	0.202
	0.246	0.362	0.183	0.182
Number of laborers	0.276	0.022	0.203	0.192
	0.186	0.27	0.136	0.134
Whether there is a steady sales channel	1.281***	1.374***	0.175	0.044
	0.337	0.31	0.237	0.22
_cons	10.807***	15.263***	2.679***	
	1.13	1.648	0.728	
N	927	927	927	927

***Indicates statistically significant at 1% level. **Indicates statistically significant at 5% level.

higher the educational level of farmers is, the more environmental awareness and scientific literacy they have, the easier they are to understand and accept the concept of sustainable agricultural management, and the more inclined they are to implement cultivated land quality protection behavior. At the 1% level, party membership is significantly positive, indicating that for farmers, party membership is conducive to improving the probability of implementing cultivated land quality protection behavior on grain family farms. This is because farmers who are party members usually have a greater sense of social responsibility, are more likely to be guided by environmental protection policies, and are more inclined to implement cultivated land quality protection behavior. Being a village cadre is positive and significant at the 1% level, which indicates that for a farmer, being a village cadre is conducive to the implementation of cultivated land quality protection behavior. The reason is that farmers who are village cadres usually have more experience in rural management and local identity and are more inclined to actively promote and implement measures related to cultivated land quality protection to promote the sustainable development of grain family farms. Non-farm work experience is positive and significant at the 5% level, indicating that non-farm work experience can promote the implementation of cultivated land quality protection behavior on grain family farms. This is because non-farm work experience exposes farmers more to modern management concepts and technologies, improves their understanding of environmental protection awareness, and thus promotes the implementation of cultivated land quality protection behavior on grain family farms to pursue sustainable agricultural development. From the perspective of the basic characteristics of farms, the scale of operation is positive and significant at the 1% level, indicating that the scale of farm operation is conducive to improving the probability of implementing cultivated land quality protection behavior on grain family farms because family farms with a larger scale of operation scale usually have more resources and management capabilities, and it is easier for them to introduce advanced agricultural technologies and scientific management methods. Thus, the probability of implementing cultivated land quality protection behavior is improved. A stable sales channel is positive and significant at the 1% level, indicating that having a stable sales channel is conducive to the implementation of cultivated land quality protection behavior on grain family farms because farms with stable sales channels can plan and implement agricultural management strategies more flexibly, not only by paying attention to short-term yields but also by considering the protection of land quality in the long run. This background of economic soundness makes them more willing to invest in cultivated land quality protection behavior and pursue sustainable development and long-term market stability.

4.2 Robustness test

The self-selection of samples should be considered when exploring the influence of participation in cooperatives on the cultivated land quality protection behavior of grain family farms. Participation in cooperatives of these farms is comprehensively affected by internal and external factors such as their own resource endowment and external environment, which means that participation in cooperatives is a non-random self-selection behavior, which in turn may lead to bias in the estimation results. In this article, the regression model is replaced to correct sample selection bias and solve the problem of self-selection. Specifically, the propensity score matching method is used to correct sample selection bias by separating participation in cooperatives from other factors affecting the cultivated land quality protection behavior of grain family farms to conduct a robustness test on the influence of cooperative participation on the cultivated land quality protection behavior of grain family farms.

Before matching estimation, the matching quality must be tested. Pirracchio and Carone's (2018) criteria were used to evaluate the balance of the propensity score matching model, as shown in Table 4. Compared with those in the pre-matching condition, the pseudo-R2, LR chi2, mean deviation, and median deviation were significantly lower after matching. Therefore, it can be concluded that the propensity score matching model can better control the variation in variables between groups, and the matching quality of the study is good.

To ensure the robustness of the matching results, three methods—nearest neighbor matching, radius matching and kernel matching—are selected for matching (Alam et al., 2019), and the results are shown in Table 5. In the case of whether cultivated land quality protection behavior is implemented on grain family farms, whether general cultivated land quality protection is implemented, and whether green cultivated land quality protection is implemented, the results obtained by the three matching methods (near neighbor matching, radius matching and kernel matching) are consistent, and the ATT value is statistically significant at the 10% level or above. Therefore, after considering the problem of sample self-selection, participation in cooperatives has a significant positive impact on the cultivated land quality protection behavior of grain family farms. In addition, in the case of the matching degree of the cultivated land quality protection of grain family farms, the three matching methods also yielded consistent results, and the average treatment effect (ATT) values were all significant at the 1% level. Therefore, participation in cooperatives had a significant positive promoting effect on the degree of cultivated land quality protection of grain family farms.

In the previous propensity score matching process, there was uncertainty in the estimated propensity score (Zhang et al., 2019). Thus, there may be bias caused by imprecise matching. It is necessary to correct possible bias by matching estimators, as described in Table 6. After correcting bias, the ATT values of Model 1, Model 2, Model 3, and Model 4 are 0.323, 0.095, 0.229, and 0.552, respectively; these values are significant at the 1% level and are greater than the ATT values in the corresponding cases before bias correction. Therefore, according to the matching estimator of the bias correction, the research conclusion is relatively robust.

4.3 Group heterogeneity analysis

The heterogeneity of the influence of participating in cooperatives on the cultivated land quality protection behavior of grain family farms was examined based on seven aspects: age, educational level, party membership, the scale of operation the years of establishment, the number of laborers, and whether the farm is a provincial demonstration farm. Based on the common practices of relevant scholars (Anderson et al., 2021), continuous variables were grouped according to whether they were at the mean level or were close to the mean level, and binary variables were grouped according to yes and no. The heterogeneity analysis results are shown in Table 7.

In general, the probability of implementing cultivated land quality protection behavior significantly increased, and the effect was greater for farms with the younger farmers, farmers of lower education level, farmers of non-party members, larger scale of operation, longer establishment years, larger labor force, or provincial demonstration. Specifically, participation in cooperatives has a significant positive impact on the implementation of cultivated land quality protection behavior among grain family farms with younger farmers, and the impact is greater than that for older grain family farmers because younger farmers are more open to new concepts and more willing to adopt advanced agricultural technology through participation in cooperatives to implement cultivated land quality protection behavior. After participating in cooperatives, family farms with farmers with a low educational level have a greater probability of implementing cultivated land quality protection. The reason is

TABLE 4 Balance test results of the propensity score matching model.

Matching method	Pseudo-R^2	LR chi^2	P-values	Mean deviation (%)	Median deviation (%)	B-values
Before matching	0.201	241.48	0	29.4	29.1	115.8
Nearest neighbor matching	0.015	24.88	0.015	7.6	6.4	29
Kernel matching	0.01	15.9	0.196	5.5	4.9	23.1
Radius matching	0.016	13.58	0.328	6.7	5.1	29.6

TABLE 5 Regression results based on the propensity score matching method.

Groups	Matching method	Treatment groups	Control groups	ATT	Standard error	Z-value
Whether implemented or not	Before matching	0.881	0.426	0.455	0.027	16.81
	Nearest neighbor matching	0.879	0.652	0.228***	0.058	3.9
	Kernel matching	0.879	0.653	0.226***	0.045	5.03
	Radius matching	0.846	0.592	0.254***	0.055	4.64
	Mean calculation	0.158				
General cultivated land quality protection	Before matching	0.114	0.019	0.096	0.019	5.17
	Nearest neighbor matching	0.112	0.039	0.074**	0.025	2.97
	Kernel matching	0.112	0.046	0.067***	0.017	3.81
	Radius matching	0.087	0.035	0.051**	0.024	2.16
	Mean calculation	0.021				
Green cultivated land quality protection	Before matching	0.766	0.407	0.359	0.031	11.61
	Nearest neighbor matching	0.767	0.613	0.154*	0.06	2.58
	Kernel matching	0.767	0.608	0.160**	0.046	3.46
	Radius matching	0.759	0.556	0.203***	0.056	3.61
	Mean calculation	0.162				
Protection degree of cultivated land quality	Before matching	2.647	1.833	0.813	0.055	14.78
	Nearest neighbor matching	2.647	2.265	0.382**	0.116	3.3
	Kernel matching	2.647	2.261	0.386***	0.089	4.32
	Radius matching	2.605	2.148	0.457***	0.108	4.21
	Mean calculation	0.313				

***Indicates statistically significant at 1% level. **Indicates statistically significant at 5% level. *Indicates statistically significant at 10% level.

that farmers with a high educational level have a good awareness of cultivated land quality protection, while farmers with a low educational level lack awareness. Therefore, participation in cooperatives has a more significant promoting effect on the implementation of cultivated land quality protection behavior among grain family farmers with low educational levels. After participating in cooperatives, the probability of implementing cultivated land quality protection behavior by grain family farms with non-party members significantly increases because non-party members may be more inclined to obtain resource support through cooperatives to compensate for the lack of organization among non-party members to promote the implementation of cultivated land quality protection behavior by grain family farms. Participation in cooperatives has a significant positive impact on the implementation of cultivated land quality protection behavior among large-scale grain family farms, and the impact is greater than that among small-scale grain family farms. After participating in cooperatives, the probability of implementing cultivated land quality protection behavior among family farms with a large labor force significantly increases, possibly because cooperatives provide collective cooperation mechanisms so that family farms with a sufficient labor force can implement cultivated land quality protection behavior more effectively. Participation in cooperatives has a significant positive impact

TABLE 6 Matching estimators for bias correction.

Variable names	Model 1 (whether impleted or not)	Model 2 (general cultivated land quality protecion)	Model 3 (green cultivated land quality protecion)	Model 4 (degree of cultivated land quality protection)
Participation in cooperatives	0.323***	0.095***	0.229***	0.552***
Other variables	Controls	Controls	Controls	Controls

***Indicates statistically significant at 1% level.

TABLE 7 Group heterogeneity analysis.

Group variables	Grouping basis	Treatment group mean	Control group mean	ATT	Z-value
Age	≤40	0.892	0.645	0.066***	3.73
	>40	0.857	0.638	0.070**	3.13
Educational level	Junior high and below	0.72	0.434	0.094**	3.05
	Junior high school or above	0.913	0.708	0.052***	3.97
Whether a party member or not	No	0.784	0.436	0.068***	5.12
	Yes	0.972	0.802	0.055***	3.09
Scale of operation	<100 acres	0.795	0.475	0.057***	5.6
	≥100 acres	0.959	0.804	0.068*	2.29
Years of establishment	<3 years	0.907	0.709	0.062**	3.18
	≥3 years	0.831	0.58	0.072**	3.49
Number of laborers	≤4 people	0.867	0.625	0.051***	4.75
	>4 people	0.898	0.75	0.118	1.26
Provincial demonstration farm or not	No	0.816	0.62	0.056**	3.48
	Yes	0.9	0.645	0.061***	4.15

***Indicates statistically significant at 1% level. **Indicates statistically significant at 5% level. *Indicates statistically significant at 10% level.

on the implementation of cultivated land quality protection on provincial demonstration farms, and the impact is greater than that on non-provincial demonstration farms. This is because after participation in cooperatives, provincial demonstration farms have richer resources and technical support, which helps them to give full play to the demonstration effect and actively implement cultivated land quality protection behavior.

5 Conclusions and suggestions

Based on survey data from 927 grain family farms in 13 major grain-producing areas in China, the effects of participation in cooperatives on the cultivated land quality protection behavior of grain family farms were analyzed by using a logit model and an ordered probit model. The robustness of the baseline regression results was tested by using the propensity score matching method, and group heterogeneity was analyzed. The following conclusions are drawn. (1) The baseline regression results show that participation in cooperatives has a significant positive effect on the implementation of cultivated land quality protection behavior and the degree of cultivated land quality protection of grain family farms. (2) The robustness test shows that after controlling for sample selection bias, participation in cooperatives has significant positive effects on both the behavior and the degree of cultivated land quality protection of grain family farms, and the ATT values are significant at the 10% level. (3) Heterogeneity analysis shows that the probability of implementing cultivated land quality protection behavior significantly increased, and the effect was greater for farms with the younger farmers, farmers of lower education level, farmers of non-party members, larger scale of operation, longer establishment years, larger labor force, or provincial demonstration. Therefore, suggestions are presented below.

First, grain family farms should be vigorously guided and encouraged to actively participate in cooperatives, information sharing and technical training should be promoted through cooperatives, and farmers should be provided with the latest agricultural scientific and technological knowledge and cultivated land management skills to improve their understanding and practices of cultivated land quality protection. The integration of resources and financial support should be strengthened through the coordinating role of cooperatives, and additional financial support and advanced agricultural equipment should be provided for grain family farms to improve their agricultural production methods and reduce adverse impacts on cultivated land. A sound reward and punishment mechanism should be established, appropriate rewards should be given to farms that implement cultivated land quality protection; enthusiasm should be stimulated; behaviors that violate the regulations on protecting the quality of cultivated land should be punished accordingly, and the sense of responsibility should be strengthened. The comprehensive operating efficiency of cooperatives should be improved, the rational use of resources should be ensured, and the cost of the cultivated land quality protection of farms should be further reduced. In addition, cooperatives should strengthen their organizational guidance to farmers, form a closer community network, encourage mutual assistance and experience sharing, change the competitive relationship into a cooperative relationship, form industry linkage, improve the market share of farm agricultural products, and enhance the influence of farm agricultural products brands.

Second, for young farmers with low educational levels, cooperatives can provide regular training on cultivated land quality protection, using easy-to-understand teaching materials and interactive learning methods to improve farmers' awareness and understanding of cultivated land quality protection. It makes them deeply understand the urgency, necessity and importance of implementing the cultivated land quality protection behavior, so that they can consciously implement the cultivated land quality protection behavior. For non-party members, a learning sharing platform can be established within cooperatives to promote communication and learning between party members and non-party members, improve non-party members' awareness of cultivated land quality protection, and form a closer atmosphere of teamwork to promote the sustainable development of cultivated land. For farms with a large scale of operation, many years of establishment and a large labor force, cooperatives can provide additional financial, technical, human and other resource support to strengthen their practical operating ability for cultivated land quality protection. By further deepening cooperation with provincial demonstration farms, cooperatives can encourage non-provincial demonstration farms to implement more active cultivated land quality protection with the help of their demonstration effect.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the [patients/participants OR patients/participants legal guardian/next of kin] was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

WD: Data curation, Investigation, Methodology, Software, Visualization, Writing – original draft. GL: Conceptualization, Investigation, Resources, Supervision, Validation, Writing – review & editing.

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Conflict of interest

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

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