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The effect of land fragmentation on farmers' rotation behavior in rural China

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Background: Arable land protection is the key to guaranteeing food security in China, as well as protecting the ecological environment and ensuring the continuous increase of farmers' income. Crop rotation is one of the many forms of arable land protection.

Objectives: In this paper, we aim to estimate the possible influence of land fragmentation, famers' willingness to rotate, and farmers' rotation behavior in China. Combining farmers' willingness to rotate and farmers' rotation behavior using the theory of intermediary effect, we determine whether the degree of land fragmentation will affect farmers' willingness to rotate or not, thereby affecting farmers' rotation behavior.

Methodology: This study based on the field survey conducted in Heilongjiang Province in 2018, focused on the impact of land fragmentation on farmers' rotation behavior through OLS and Probit model. Specifically, the degree of land fragmentation and farmers' willingness to rotate are 0.187 and 0.463, respectively. Further, by taking the farmers' willingness to rotate as the mediator, this paper discusses the mechanism on the effect of land fragmentation on farmers' rotation behavior. Finally, the farmers are divided into large and small farmers—according to acreage for heterogeneity analysis.

Main findings: This study found that the degree of land fragmentation affects farmers' willingness to rotate, thereby having some mediating effects on farmers' rotation behavior.

Conclusion: The indirect impact accounts for only 39.86% of the total impact, and more comes from the direct impact. Thus, policy makers should strengthen the guidance for farmers to stimulate their behavior and willingness to implement rotation. Furthermore, it is vital to improve the popularization of arable land protection knowledge and increase crop rotation subsidies.

KEYWORDS
arable land, land fragmentation, rotation, willingness to rotate, mediating effects

1 Introduction

Various ecological problems have become increasingly prominent due to the accelerated growth of urbanization. Ecological security and conservation have recently become an important hot issue (Yu et al., 2021). In April 2013, during the inspection in Hainan, President Xi Jinping emphasized that "a good ecological environment is the most equitable public good and allows for the most inclusive people's livelihood." (http://politics.people.com.cn/n/2013/0410/c1024-21090468.html accessed on 10 April 2013) In the following 5 years, China has strengthened its policies concerning the ecological environment. In June 2018, the CPC Central Committee and the State Council issued Opinions on Comprehensively Strengthening Ecological and Environmental Protection and Resolutely Fighting a Tough Battle for Pollution Prevention and Control to ensure a fundamental improvement in the quality of the ecological environment and in the economic policy and legal system for ecological and environmental protection. The development of green and low-carbon recycling economy and improving comprehensive energy and resource conservation were promoted to achieve the goal of building a beautiful China (http://www.gov.cn/zhengce/2018-06/24/content_5300953.htm?trs=1 accessed on 24 June 2018).

Northeast China is one of the largest producers of grain in the country. In 2020, in the main grain producing areas, the output of corn, rice, and soybean in Heilongjiang Province were 36.466 million tons, 28.962 million tons, and 9.203 million tons, respectively, accounting for 98.97% of the total grain output of the province, providing sufficient guarantee for the supply of grain crops throughout the country. Northeast China, including Liaoning, Jilin, and Heilongjiang provinces. Northeast China has superior agricultural natural conditions, rich industrial natural resources, and prominent geographical relations and strategic position (Li and Chen, 2017). However, in recent years, with the increase in population and the over exploitation of resources, the ecological environment in this area has been deteriorating (Li et al., 2010a). In May 2017, the Ministry of Agriculture issued the action plan for straw treatment in Northeast China to increase farmers' income and the quality of cultivated land, as well as to promote ecological and environmental protection (http://www.kjs.moa.gov.cn/hbny/201904/t20190418_6185480.htm accessed on 18 May 2017). In recent years, the preservation and development of the ecological environment in Northeast China has achieved remarkable results. In terms of high-quality economic and social development, Northeast China needs more support and help from the state, and internal regional linkages must be strengthened to build an ecological coordination mechanism.

The black soils in Northeast China play an important role in food security for the Chinese population of 1.4 billion (Liu et al., 2021). According to the data provided by the Office of the Leading Group for the Preparation of National Water and Soil Conservation Planning, the total area of black soil area is 1.09 million square kilometers, accounting for about 12% of the total area of the global black soil area. However, over the past few decades, the black soil layer has decreased by an average of 1 cm per year. The thickness of black soils is 80–100 cm at the initial stage of reclamation, while it is only 20–40 cm at present (Chen et al., 2021). In recent years, the quantity and quality of soil organic matter cultivated in black soils in Northeast China have decreased rapidly due to natural and artificial factors; hence, the urgent protection of black soils is necessary (Yan et al., 2021). Due to overexploitation and unsustainable management measures, the soil organic matter in this area is declining as well as the quality of cultivated land (Du et al., 2021). This has led to the long-term exposure of black soil, degradation of soil structure, and aggravation of wind and water erosion in some parts of Northeast China, which poses a severe challenge to the sustainable development of agriculture and the guarantee of food security in Northeast China. According to the 2020 data from the China Soil and Water Conservation Bulletin, the area of black soil erosion in the northeast is 2,16,000 square kilometers, accounting for 19.86% of the total black soil area, and the black soil layer is decreasing at an average annual rate of 0.1–0.5 cm erosion loss. Thus, effective protection and utilization of northeast black soil resources is an important measure to ensure food security and sustainable development in China (Kamil, 2020). FAO (Food and Agriculture Organization of the United Nations) defines conservation agriculture as an agricultural system that promotes minimal soil disturbance, maintains permanent soil cover, and diversifies plant species. It enhances biodiversity and natural biological processes above and below the surface, improves the efficiency of water and nutrient use, and sustains crop production (https://www.fao.org/conservation-agriculture/en/accessed in 2021). In March 2020, the Ministry of Agriculture and Rural Affairs and the Ministry of Finance of the People's Republic of China jointly issued the Northeast Black Soil Conservation Tillage Action Plan (2020–2025) at the national level to raise the implementation of conservation tillage in Northeast China. It is necessary and feasible to strengthen policy guidance and change the traditional farming system to curb the degradation of black soil, restore and enhance the fertility of cultivated land, and strengthen the foundation of national food security (http://www.gov.cn/xinwen/2020-03/18/content_5492780.htm accessed 18 March 2020).

Land fragmentation, wherein a household operates more than one separate plot of land, is a vital factor restricting agricultural development (Tran and Vu, 2019), which is the most feature of China. Some studies confirm that land fragmentation may have positive effects. Those who support this view believe farmers who possess several minute and diverse parcels of land spread out spatially generally means that they had access to a greater variety of soils for cultivation when facing the risk of natural disasters (Shaw, 1963). Also, land fragmentation allows farmers allocate production factors to increase land productivity and food diversification, acceptability, accessibility according to different plots (Bentley, 1987; Ntihinyurwa and Vries, 2021). At the same time, a variety of crops can be planted in different plots to reduce market risks and farmers' exposure to weather variability (Benin et al., 2004; Ntihinyurwa et al., 2019). However, many previous studies have shown that the existence of land fragmentation has negative effects. Many researchers find that land fragmentation is related to lower agricultural output and reduced productivity in settings as diverse as rural China (Nguyen et al., 1996; Wan and Cheng, 2001), which tends to be associated with high cost of production, particularly in terms of labour, because of the amount of time spent getting into spatially separated parcels (Van Hung et al., 2007). In other words, smaller and more fragmented parcels of cultivated land hinder mechanization, increase fixed costs such as fences, and adds to the possibility of land disputes (Demetriou et al., 2013). Previous studies indicated that about 3%–10% of effective arable land was wasted due to the land fragmentation in China (Xiang, 2010). Many research shows that the more serious the degree of land fragmentation, the lower the efficiency of agricultural management and the lower the utilization rate of agricultural machinery, which directly leads to the reduction of cultivated land area (Li et al., 2010b). Furthermore, the impact of land fragmentation on farmers who mainly grow grain is also serious, mainly because the degree of land fragmentation is closely related to the operation scale of cultivated land and the income of farmers, which determines the quality of life and living environment of farmers to a certain extent (Van den Berg et al., 2007). Much of existing research on it focus on food security, crop productivity, and farmer income, but there is a lack of research data on the parcel of land involved and a research method combining land fragmentation, farmers' willingness to rotate, and farmers' rotation behavior. Our findings make a contribution to fills this gap. We used OLS and Probit model to estimate the impact of land fragmentation on farmers' rotation behavior. Furthermore, according to acreage for heterogeneity analysis, the farmers are divided into large and small farmers.

In terms of arable land protection, the key to maintaining and improving the quality of arable land lies in how to motivate farmers to practice its continuous and effective protection. Academic research on the potential influencing factors of arable land protection behavior has achieved good results, among which are the farmers' age and agricultural income (Molnar, 1985; Yu et al., 2014), educational level, (Wu, 2018) and the period of residence of part-time farmers in the local area (Wilson, 1997). Similarly, the area of rocky desertification (Yu et al., 2014), the publicity of arable land protection, and the level of local economic development (Wu, 2018) are also important influencing factors affecting farmers' arable land protection. Some scholars mentioned that the "empathy" of the pursuit of the public interest have influenced farmers' arable land decision-making behavior in the psychological level, which in turn has made farmers inclined to conservation tillage (Supalla, 2003; Chouinard et al., 2008); however, these studies are mainly theoretical analyses and lack data and empirical research. Sheeder and Lynne (2011) empirically analyzes the impact of compassion on farmers' adoption of conservation tillage and finds that the more compassionate farmers are, the more likely they are to adopt conservation tillage (Sheeder and Lynne, 2011). Research on conservation tillage has focused on its benefits (Zhang et al., 2012; Dai et al., 2021; Madarász et al., 2021), its present implementation, and the problems with its extension (He et al., 2010; Pedersen et al., 2012; Wang et al., 2016), among others. The results show that conservation tillage is of vital significance to the improvement of cultivated land quality and grain yield.

In aspect of research on farmer behavior, the existing research mostly discuss the factors influencing crop rotation behavior through internal characteristics and external key factors (Grabowski and Kerr, 2014; Mann, 2018; Ntshangase et al., 2018). In the previous studies, farmers with greater environmental awareness pay more attention to rural land protection (Beedell and Rehman, 2000). As for policy tools, scholars often study its impact on macro land use changes (Schieffer and Dillon, 2015; Kuang et al., 2020) or explore specific incentive policies (Barry et al., 2014; Brown et al., 2018). Some scholars also research the effect of policy stimuli, proving that policies can effectively stimulate farmers' behavior (Barry et al., 2014; Schieffer and Dillon, 2015; Kaine et al., 2017). Existing research methods on farmers' behavior focus on simple linear regression models such as logistic regression (Yadav et al., 2021) or structural equation models (Aregay et al., 2018) for quantitative analysis.

The willingness to arable land protection plays an important role in preserving the rural ecological environment. Foreign scholars have conducted several studies on the influencing factors of arable land protection intention, which are mainly reflected in a number of aspects. First, in terms of the certainty of cultivated land management right, the uncertainty of land tenure will hinder farmers from adopting conservation tillage technology (Bewket, 2007). Second, in the aspect of the individual characteristics of farmers, the impact of age, educational level, non-agricultural income, length of residence, and other factors on farmers' adoption of conservation tillage technology (Wilson, 1997). Among them, the longer the period of residence, the more farmers tend to adopt conservation tillage. The factors affecting farmers' actual protective measures include environmental degradation (Traoré et al., 1998), farmers' education level, expected crop loss, the impact of pesticide use on health, and the availability of sufficient information on best management practices. In addition, the higher the level of education, the stronger the farmers' awareness of protecting cultivated land (Mbaga-Semgalawe and Folmer, 2000; Vignola et al., 2010). Third, in the aspect of policy encouragement, higher incentives had a positive impact on respondents' willingness to install buffers (Lynch et al., 2002). As crop input management decisions become more complex and technical assistance becomes more challenging, the provision of expert advice may help promote the adoption of specialized conservation practices (Lambert et al., 2007). Fourth, in terms of environmental awareness, cognitive and psychological variables such as belief in soil protection and sense of responsibility for soil management have a positive impact on the adoption of soil protection measures (Lynne et al., 1988; Gould et al., 1989). The awareness of environmental issues was improved through education, membership of producer organizations, and participation in government funded agricultural projects (Traoré et al., 1998). Also, farmers' perception of the probability and severity of climate related events and the final perceived coping ability are the determinants of farmers' coping behavior (Grothmann and Patt, 2005).

Domestic scholars on farmer willingness to rotate are fewer, previous studies found that farmers' age, education level, annual household income, per capita arable land area per household, and dependence on land resources are the five basic and universal factors that influence farmers' willingness to rotate (Chen et al., 2005). The older farmers are, the stronger their awareness of arable land protection. In addition, land fragmentation and the decline in the proportion of agricultural income will lead to the reduction of farmers' willingness to protect (Zhao et al., 2008). However, there is a lack of research on the influencing factors that combine the willingness and behavior of arable land protection, which is the problem to be discussed in this paper.

To address this gap, this study aims to estimate the possible influence of land fragmentation, famers' willingness to rotate, and farmers' rotation behavior in China. Combining farmers' willingness to rotate and farmers' rotation behavior using the theory of mediating effect, we determine whether the degree of land fragmentation will affect farmers' willingness to rotate or not, thereby affecting farmers' rotation behavior. Further, large and small farmers were divided based on acreage and were estimated to explore whether there is different mediating effect between them. Despite these important findings, this study has several limitations. Considering the time and financial costs, our study focused on the main grain producing areas. The lessons learned from the present study may not be generalizable to other areas of China. Also, the age of the farmers in the sample is about 50 years old, and cognitive gaps limited by age are not fully discussed in this paper. Under the perspective of intergenerational, the new and middle generations are more willing to preserve agricultural land than the older generation (Zhao et al., 2008), the impact of land fragmentation on farmers' age is not significance in our study.

The remainder of this paper is structured as follows. Section 2 analyzes the investigation data. Section 3 describes the methodology and the mediation model. Section 4 presents empirical results, and Section 5 concludes the study.

2 Statistical methods

2.1 Data collection and definition of variables

We select samples according to the accumulated temperature zone (the sum of the daily average temperature during the continuous period of daily average temperature ≥10°C in a year, i.e., the sum of active temperature, referred to as accumulated temperature, which is an index to study the relationship between temperature and the development speed of biological organisms). Most of them are sample counties in the third and fourth accumulated temperature zone. We use multi-stage sampling in this research. First, we selected 15 counties from Heilongjiang Province according to the distribution of accumulated temperature zone using the probability scale proportional sampling (PPS). Second, we chose three towns from each sample county according to the per capita industrial output value through the equidistant sampling method. Finally, we randomly selected three villages from each town, and then randomly choose 10 farmers from each village.

In Table 1, farmers' rotation behavior and rotation intention were 56.0% and 75.2%, respectively, indicating that most farmers have relatively high intention of arable land protection. The key independent variable in this study is the degree of land fragmentation, and its mean value is 0.654.

The most frequently used tool to measure fragmentation is the Simpson index (Blarel et al., 1992), which was used in this study to reflect the degree of land fragmentation. To assess the degree of fragmentation, the Simpson index we used is as follows:

$$SI = 1 - \sum_{i=1}^{n} a_i^2 / \left(\sum_{i=1}^{n} a_i\right)^2 \quad (1)$$

where SI denotes the degree of land fragmentation, which is bounded between 0 and 1; the greater its value, the higher the degree of land fragmentation. When $SI = 0$, the farmers have only one piece of land, and when $SI = 1$, the fragmentation is worst. In Eq. 1, a_i refers to the area of each plot i, and n denotes the number of plots. We select the gender, age, whether the village leader, whether the party member, years of education and land area of farmers as control variables. In the control variables, and the mean value of sample gender is 0.988, indicating that most farmers involved are males. We asked farmers whose families mainly make decision about farming, which is why the proportion of male is so high. The age of the farmers in the sample is about 50 years old, indicating that the main labor force in rural areas is the elderly. Among them, the average educational level of farmers is 7.931, which means the educational level of the main labor force in rural areas is not high, and most of them have not completed the 9-year compulsory education.

2.2 Descriptive statistics

Based on the above main variables, we analyze the differences between the two sample groups in each variable by distinguishing whether farmers have rotation intention or not, and obtain the descriptive statistics. Among them, 981 farmers have rotation intention, accounting for 75.23% of the total sample, while 323 farmers had no rotation intention, accounting for 24.77% of the total sample in Table 2.

There are significant differences in rotation behavior between farmers with rotation intention and farmers without rotation intention. Specifically, the average land fragmentation index of farmers with rotation intention is 0.668, which is 0.056 higher than the average of 0.612 of farmers without rotation intention. In terms of other variables, there are still significant differences between farmers with and without rotation intention, and the average value of farmers with rotation intention is higher than that of farmers without rotation intention. Specifically, the average value of rotation behavior of farmers with rotation intention is 0.712, which is much higher than the average value of 0.099 of farmers without rotation intention. Furthermore, in the control variables, the acreage has significant differences between farmers with rotation intention and farmers without rotation intention. Specifically, the average value of acreage of farmers with rotation intention and farmers without rotation intention are 46.387 and 27.072, respectively, indicating that the role of farmers' rotation intention in farmers' rotation behavior is extremely significant.

In order to further explore the impact of land fragmentation on farmers' behavior of arable land protection and the possible mechanism, we use the OLS and Probit model to estimate.

3 Methodology

3.1 Estimation method

We use the OLS model to estimate the influence of land fragmentation on farmers' rotation behavior, as follows:

$$\boldsymbol{Y_i = \alpha_0 + \alpha_1 SI_i + \alpha_2 X_i + \varepsilon_i} \quad (2)$$

where Y is the dependent variable that denotes whether the farmers have rotation behavior or not, and SI_i denotes the degree of land fragmentation (between zero to one). α_1 is the coefficient for land fragmentation, which we are focusing on, and measures the impact of land fragmentation on farmers' rotation behavior. X is a vector of exogenous control variables, such as the gender, age, party membership, education level, cadres of the farmers and acreage. α_2 is the related coefficient vector. α_0 is the intercept, and ε is a random error that exists in normal distribution. i represents each of the observations.

The dependent variable of this paper is whether farmers implement crop rotation behavior or not, which includes two aspects: Yes and No. This requires ensuring that the short-cut process of the dependent variable is 0 or 1 in the empirical analysis. Therefore, we used the Probit model, a non-linear regression model specifically designed for binary dependent variables, which are y (0 = farmers have no rotation in the recent 5 years; 1 = farmers have rotation in the recent 5 years), and X, the degree of land fragmentation (between zero to one), as follows:

$$\boldsymbol{Pr(y = 1|X) = \Phi(\beta_0 + \beta_1 X)} \quad (3)$$

where Φ is the cumulative standard normal distribution function. For the convenience of calculating probabilities, we used the Probit model instead of the Logit model, because the Logit model allows more extreme observations while the Probit model assumes a normal distribution.

3.2 Mediation model

In this research, we hypothesized that farmers implement crop rotation behavior based on their willingness to rotate, which acts as the mediating variable. Therefore, a mediation model was used in this study. Mediation analysis involves statistical methods used to respond to how an independent variable, X (the degree of land fragmentation), transmits its effect on a dependent variable, Y (farmers' rotation behavior), and this effect is "mediated" by another variable (Hayes, 2013), M (farmers' willingness to rotate) (Hayes, 2013). According to MacKinnon et al. (2007), the "mediator is a variable that is in a causal sequence between two variables, whereas a moderator is not part of a causal sequence between the two variables" (MacKinnon et al., 2007). In other words, the variable M is intermediate in the causal trajectory of X and Y and represents an asymmetrical relationship between such variables. Therefore, a mediating effect model is established to test the impact mechanism.

The following shows the impact mechanism model of farmers' rotation behavior:

Based on the above analysis, the mediator in this paper is the farmers' willingness to rotate. The refinement of the above model is as follows:

$$\boldsymbol{Y_i = \alpha_0 + \alpha_1 SI_i + \alpha_2 X_i + \varepsilon_i} \quad (4)$$

$$\boldsymbol{W_i = \delta_0 + \delta_1 SI_i + \delta_2 X_i + \varepsilon_2} \quad (5)$$

$$\boldsymbol{Y_i = \eta_0 + c_1 SI_i + b_1 W_i + \eta_1 X_i + \varepsilon_3} \quad (6)$$

where Y is the dependent variable that denotes whether the farmers have rotation behavior or not, and W is the mediator which shows whether the farmers are willing to rotate or not. α_1 is the coefficient for the impact of land fragmentation on farmers' rotation behavior, and δ_1 is the coefficient for the mediating effect of land fragmentation on farmers' willingness to rotate. b_1

TABLE 1 Definitions of variables.

Variables	Description	Mean	SD	Min	Max
Farmers' rotation behavior	Farmers whether have rotation in recent 5 years	0.560	—	0	1
Farmers' rotation intention	Farmers whether have rotation intention	0.752	—	0	1
Land fragmentation	Fineness degree of arable land	0.654	0.225	0	0.902
Gender	Dummy; 0 = female; 1 = male	0.988	—	0	1
Age	The age of farmer	49.93	9.241	26	85
Party membership	Dummy; 0 = non-party member; 1 = party member	0.180	—	0	1
Education level	The educational years of farmer	7.931	2.600	1	16
Cadres	Dummy; 0 = not cadres; 1 = cadres	0.153	—	0	1
Acreage	The lands area cultivated of farmer	41.60	80.40	1	745

Source: Authors' survey.

TABLE 2 Descriptive statistics of variables.

Variables	Willingness = 1		Willingness = 0		Difference
	Mean	Std. dev.	Mean	Std. dev.	
Farmers' rotation behavior	0.712	0.453	0.099	0.299	0.613***
Land fragmentation	0.668	0.218	0.612	0.241	0.056***
Gender	0.991	0.095	0.981	0.135	0.009
Age	50.072	9.054	49.495	9.789	0.577
Party membership	0.164	0.371	0.118	0.323	0.047**
Education level	0.191	0.393	0.149	0.356	0.042*
Cadres	8.025	2.602	7.644	2.576	0.381**
Acreage	46.387	89.01	27.072	42.01	19.315***
Number of Obs		981		323	

Note: ***, **, and * are their significance at the levels of 1%, 5%, and 10%, respectively.

is the coefficient for the indirect effect of farmers' willingness to rotate on farmers' rotation behavior, and c_1 is the coefficient for the direct effect of land fragmentation on farmers' rotation behavior after controlling the impact of farmers' willingness to rotate. α_0, δ_0, η_0 are the intercepts, and ε_i, ε_2, ε_3 are random errors that exist in normal distribution. i represents each of the observations.

4 Empirical results and discussion

4.1 Estimation results of OLS and probit model

This study focuses on the impact of land fragmentation on farmers' rotation behavior through OLS and Probit mode based on the field survey conducted in Heilongjiang Province in 2018. Specifically, the degree of land fragmentation and farmers' willingness to rotate are 0.187 and 0.463, respectively. The results, as presented in Table 3, show that the coefficient of the degree of Land fragmentation is positive and significant at the significance level of 1%, indicating that land fragmentation has a significant positive effect on farmers' rotation behavior in Model 1. The higher the degree of land fragmentation, the more rotation behavior. Furthermore, the coefficient of farmers' willingness to rotate is positive and significant at the significance level of 1%, indicating that farmers' rotation intention will positively affect farmers' rotation behavior. This means that the more farmers are willing to rotate, the more they will carry out actual rotation behavior. For the control variables, acreage has a significant impact on farmers' rotation behavior at the significance level of 5%. However, farmers' gender, age, party membership, and their education level have little impact on farmers' rotation behavior. Whether farmers are village cadres is significant at the significance level of 10%,

TABLE 3 Estimation results of land fragmentation on farmers' rotation behavior.

Variable	OLS	Probit	Marginal effect of probit
	(1)	(2)	(3)
Farmers' willingness to rotate	0.463***	1.616***	0.397***
	(0.027)	(0.117)	(0.022)
Land fragmentation	0.187***	0.796***	0.196***
	(0.050)	(0.205)	(0.050)
Acreage	0.000**	0.002**	0.000
	(0.000)	(0.001)	(0.000)
Gender	0.009	0.077	0.019
	(0.099)	(0.435)	(0.107)
Age	0.001	0.006	0.001
	(0.001)	(0.005)	(0.001)
Cadres	−0.059*	−0.194	−0.048
	(0.035)	(0.140)	(0.034)
Party membership	0.047	0.178	0.044
	(0.033)	(0.137)	(0.034)
Education level	0.007	0.026	0.006
	(0.004)	(0.018)	(0.004)
Fixed effect of country	Yes	Yes	Yes
Constant term	−0.266*	−2.912***	
	(0.137)	(0.575)	
Number of obs	1,304	1,304	1,304
R-Squared	0.415	0.365	

Note: ***, **, and * are their significance at the levels of 1%, 5%, and 10%, respectively.

indicating that farmers having a certain mastery of arable land protection knowledge will promote their rotation behavior.

Combined with the results of Models 2 and 3, the degree of land fragmentation is significantly positively correlated with farmers' rotation behavior at the significance level of 1%, with a marginal effect of 19.6%, indicating that the more serious the land fragmentation, the more farmers will carry out rotation behavior to improve the quality of cultivated land. Similarly, there is also a significant relationship between farmers' willingness to rotate and farmers' rotation behavior. Specifically, it has impact at the significance level of 1%, with a marginal effect of 39.7%. Through the estimation of the Probit model, it can be concluded that the more serious the land fragmentation and the higher the farmers' willingness to protect arable land, the more farmers will protect cultivated land.

4.2 Mediating effect results

We analyzed each regression results according to the mediation effect estimation process modified (Wen and Ye, 2014).

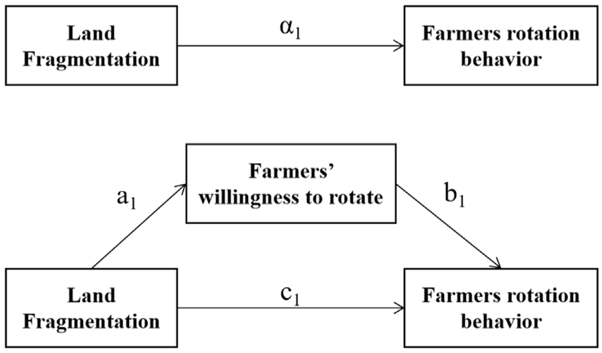

FIGURE 1
The influence mechanism of Land fragmentation on Farmer's rotation behavior.

First, we examine whether the total regression meets the first requirement of mediating effect in Model 4, that is, whether its coefficient is significant. It can be seen from the results that the degree of land fragmentation significantly affects whether farmers have rotation behavior or not. Specifically, the farmers with rotation are about 0.187 higher than those without rotation, and this difference has passed the significance test at the level of 1%. Second, we estimate whether the coefficients a_1 and b_1 are significant. The results show that a_1 is significantly positive at the significance level of 1%, which means land fragmentation has a positive impact on farmers' rotation behavior; b_1 is significant at the significance level of 1%, which means that farmers' willingness to rotate has a positive impact on farmers' rotation behavior. The stronger the farmers' willingness to rotate subjectively, the more they will practice rotation behavior. Furthermore, the product of a_1 and b_1 is positive and has the same sign as c_1. It shows that farmers' willingness to rotate has some mediating effects on the impact of land fragmentation and whether farmers practice rotation or not; the degree of land fragmentation can promote farmers' rotation behavior by strengthening farmers' willingness to rotate. It can be calculated that the partial mediation is $a_1{*}b_1 = 0.161{*}0.463 = 0.075$, and the total effect is 0.187. Therefore, the mediating effect is $\frac{a_1{*}b_1}{c_1}{*}100\% = \frac{0.075}{0.187}{*}100\% = 39.86\%$ of the total effect; the influence mechanism in Figure 1 is established.

4.3 Heterogeneity analysis

The empirical results above in Table 4 show that land fragmentation has a positive impact on farmers' rotation behavior. However, in the process of agriculturalization, arable land becomes uneven in rural areas. Based on the descriptive

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TABLE 4 Estimation results of mediating effect model of farmers' willingness to rotate.

Variable	Farmers' rotation behavior	Farmers' willingness to rotate
	(4)	(5)
Farmers' willingness to rotate	0.463***	
	(0.027)	
Land fragmentation	0.187***	0.161***
	(0.050)	(0.052)
Acreage	0.000**	0.000
	(0.000)	(0.000)
Gender	0.009	0.083
	(0.099)	(0.102)
Age	0.001	0.004***
	(0.001)	(0.001)
Cadres	−0.059*	0.016
	(0.035)	(0.036)
Party membership	0.047	−0.014
	(0.033)	(0.034)
Education level	0.007*	0.005
	(0.004)	(0.005)
Fixed effect of country	Yes	Yes
Constant term	−0.266*	0.276**
	(0.137)	(0.140)
Number of obs	1,304	1,304
R-Squared	0.415	0.183

Note: ***, **, and * are their significance at the levels of 1%, 5%, and 10%, respectively.

statistics of the primary variable, it is concluded that the average land area of each household in the study area is 42 mu. In the next step, the farmers who have a cultivated land area greater than or equal to 42 mu are defined as large farmers, while those with a cultivated land area less than 42 mu are defined as small farmers. The discussion below is a heterogeneity analysis based on this.

As shown in Table 5, small farmers' willingness to rotate has a significant and positive guiding effect on farmers' rotation behavior at the significance level of 1%, and the degree of land fragmentation has a significant and positive impact on farmers' rotation behavior and farmers' willingness to rotate at the significance level of 1% and 5%, respectively. This indicates that the higher the degree of land fragmentation, the smaller farmers are willing to implement rotation. Moreover, the mediating effect plays a vital impact in the heterogeneity analysis of small farmers. Specifically, the mediating effect is $a_{1s}*b_{1s} = 0.170*0.437 = 0.743$, and the total effect is 0.216. Therefore, the mediating effect is $\frac{a_{1s}*b_{1s}}{c_{1s}}*100\% = \frac{0.743}{0.216}*100\% =$ 34.39% of the total effect, which means they have crop rotation intention and would practice rotation behavior to ensure the quality of arable land, so that it will not affect the crop yield due to over tillage.

The impact of large farmers' willingness to rotate on farmers' rotation behavior is significant at the significance level of 1%, which is positive, but the degree of land fragmentation has no significant impact on farmers' willingness to rotate and farmers' rotation behavior. Therefore, for large farmers, the degree of land fragmentation does not affect their willingness to conduct conservation tillage and arable land protection subjectively, that is, there is no mediating effect for large farmers. Furthermore, it can also be seen that the impact of rotation willingness of large farmers on rotation behavior is 0.144 higher than that of small farmers. This indicates that farmers with more land area may be more willing to implement rotation behavior on arable land, and they will be better at maintaining the quality of arable land to ensure greater yield. Land fragmentation index of large farmers and small farmers are 0.14 and 0.22, respectively. According to the "2016 Heilongjiang Province crop rotation subsidy pilot implementation plan" of the Heilongjiang Provincial Agricultural Committee, the policy encourages the rotation of centralized and continuous land and gives crop rotation subsidies, which explains that for large households they will rotate their crops no matter what.

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TABLE 5 Heterogeneity analysis of small and large farmers.

Variable	Small farmers		Large farmers	
	Farmers' rotation behavior	Farmers' willingness to rotate	Farmers' rotation behavior	Farmers' willingness to rotate
	(6)	(7)	(8)	(9)
Farmers' willingness to rotate	0.437***		0.581***	
	(0.030)		(0.066)	
Land fragmentation	0.216***	0.170***	0.137	0.117
	(0.058)	(0.061)	(0.102)	(0.096)
Acreage	0.001	−0.001	0.000***	0.000
	(0.001)	(0.001)	(0.000)	(0.000)
Gender	−0.003	0.137	0.220	−0.220
	(0.108)	(0.112)	(0.251)	(0.236)
Age	0.002	0.005***	−0.002	−0.002
	(0.001)	(0.001)	(0.003)	(0.003)
Cadres	−0.044	0.064	−0.102	−0.100*
	(0.041)	(0.042)	(0.065)	(0.061)
Party membership	0.026	−0.043	0.107	0.065
	(0.038)	(0.039)	(0.066)	(0.062)
Education level	0.007	0.007	0.009	0.001
	(0.005)	(0.005)	(0.010)	(0.010)
Fixed effect of country	Yes	Yes	Yes	Yes
Constant term	−0.295*	0.191	−0.316	0.830***
	(0.154)	(0.160)	(0.316)	(0.293)
Number of obs	1,042	262		
R-Squared	0.411	0.182	0.483	0.292

Note: ***, **, and * are their significance at the levels of 1%, 5%, and 10%, respectively.

5 Conclusion

The issue of arable land protection has always been the top priority for rural development in China. This study combines farmers' willingness to rotate and farmers' rotation behavior to estimate the possible influential pathway through which the degree of land fragmentation may affect farmers' rotation behavior, thereby affecting farmers' willingness to rotate. By using data from Heilongjiang Province in Northeast China, this study draws the following conclusions. First, the degree of land fragmentation is high. Specially, the average land fragmentation index of farmers with rotation intention is 0.668, which is 0.056 higher than the average of 0.612 of farmers without rotation intention. Second, the ratio of farmers' willingness to rotate and their rotation behavior is high, but there is a disparity between willingness and behavior. Specifically, the degree of land fragmentation and farmers' willingness to rotate are 0.187 and 0.463, respectively. Moreover, the estimation results of the mediation models show that the mediation effects of farmers' willingness to rotate was small but significant. Specifically, the mediating effect is 39.86% of the total effect, which means that there is a partial mediation effect. In addition, the mediating heterogeneity effect between large and small farmers are different. For small farmers, the mediating effect is 34.39% of the total effect, but there is no mediating effect for large farmers.

Considering the heterogeneity between subgroups of mediating effects, agricultural practitioners and policy makers should adopt multi-aspect intervention policies to not only to promote through multiple channels, but also subsidies should be provided to encourage farmers to carry out crop rotation. First, the government and society must conduct vigorous information campaigns on the specific form, necessity, and implication of conservation tillage due to the gap crop rotation ratio and the willingness to rotate. Second, we should pay more attention to small farmers who make up the majority of this group. And the government should include small farmers into the scope of subsidy when formulating the crop rotation subsidy policy.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

Conceptualization, QZ; Methodology, BY and YD; Software, QZ and YD; Validation, YD, QZ, and BY; Formal analysis, BY and YD; Investigation, QZ; Resources, QZ; Data curation, QZ and YD; Writing—original draft preparation, BY and YD; Writing—review and editing, QZ, BY, and YD; Visualization, YD; Supervision, QZ and BY; All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

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References

Aregay, F. A., Minjuan, Z., and Tao, X. (2018). Knowledge, attitude and behavior of farmers in farmland conservation in China: An application of the structural equation model. *J. Environ. Plan. Manag.* 61, 249–271. doi:10.1080/09640568.2017.1301895

Barry, L. E., Yao, R. T., Harrison, D. R., Paragahawewa, U. H., and Pannell, D. J. (2014). Enhancing ecosystem services through afforestation: How policy can help. *Land Use Policy* 39, 135–145. doi:10.1016/j.landusepol.2014.03.012

Beedell, J., and Rehman, T. (2000). Using social-psychology models to understand farmers' conservation behaviour. *J. Rural Stud.* 16, 117–127. doi:10.1016/S0743-0167(99)00043-1

Benin, S., Smale, M., Pender, J., Gebremedhin, B., and Ehui, S. (2004). The economic determinants of cereal crop diversity on farms in the Ethiopian highlands. *Agric. Econ.* 31, 197–208. doi:10.1016/j.agecon.2004.09.007

Bentley, J. W. (1987). Economic and ecological approaches to land fragmentation: In defense of a much-maligned phenomenon. *Annu. Rev. Anthropol.* 16, 31–67. doi:10.1146/annurev.an.16.100187.000335

Bewket, W. (2007). Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers. *Land Use Policy* 24, 404–416. doi:10.1016/j.landusepol.2006.05.004

Blarel, B., Hazell, P., Place, F., and Quiggin, J. (1992). The economics of farm fragmentation: Evidence from Ghana and Rwanda. *World Bank. Econ. Rev.* 6, 233–254. doi:10.1093/wber/6.2.233

Brown, B., Nuberg, I., and Llewellyn, R. (2018). Constraints to the utilisation of conservation agriculture in Africa as perceived by agricultural extension service providers. *Land Use Policy* 73, 331–340. doi:10.1016/j.landusepol.2018.02.009

Chen, M. Q., Deng, A. Z., Zhou, B. J., Liu, Z. T., Wu, P., and He, W. J. (2005). Empirical study on cultivated land protection mentality of different groups of farmers. *China soft Sci.* 9, 16–22. doi:10.3969/j.issn.1002-9753.2005.09.003

Chen, W. F., Hans-Joachim, B., Huang, J. K., and Emmanuel, O. (2021). Innovative development of seed industry, building a global food security barrier. *Sci. Technol. Her.* 39, 65–70. doi:10.3981/j.issn.1000-7857.2021.16.013

Chouinard, H., Paterson, T., Wandschneider, P., and Ohler, A. (2008). Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. *Land Econ.* 84, 66–82. doi:10.3368/le.84.1.66

Dai, Z., Hu, J., Fan, J., Fu, W., Wang, H., and Hao, M. (2021). No-tillage with mulching improves maize yield in dryland farming through regulating soil temperature, water and nitrate-N. *Agric. Ecosyst. Environ.* 309, 107288. doi:10.1016/j.agee.2020.107288

Demetriou, D., Stillwell, J., and See, L. (2013). A new methodology for measuring land fragmentation. *Comput. Environ. Urban Syst.* 39, 71–80. doi:10.1016/j.compenvurbsys.2013.02.001

Du, Z., Gao, B., Ou, C., Du, Z., Yang, J., Batsaikhan, B., et al. (2021). A quantitative analysis of factors influencing organic matter concentration in the topsoil of black soil in northeast China based on spatial heterogeneous patterns. *ISPRS Int. J. Geoinf.* 10, 348. doi:10.3390/ijgi10050348

Gould, B. W., Saupe, W. E., and Klemme, R. M. (1989). Conservation tillage: The role of farm and operator characteristics and the perception of soil erosion. *Land Econ.* 65, 167–182. doi:10.2307/3146791

Grabowski, P. P., and Kerr, J. M. (2014). Resource constraints and partial adoption of conservation agriculture by hand-hoe farmers in Mozambique. *Int. J. Agric. Sustain.* 12, 37–53. doi:10.1080/14735903.2013.782703

Grothmann, T., and Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Glob. Environ. Change* 15, 199–213. doi:10.1016/j.gloenvcha.2005.01.002

Hayes, A. F. (2013). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Available at: https://www.semanticscholar.org/paper/Introduction-to-Mediation%2C-Moderation%2C-and-Process-Hayes/0316f2bc77021bcf6499374213ffec0a95926dd9 (Accessed February 10, 2022).

He, J., Li, H., Kuhn, N. J., Wang, Q., and Zhang, X. (2010). Effect of ridge tillage, no-tillage, and conventional tillage on soil temperature, water use, and crop performance in cold and semi-arid areas in Northeast China. *Soil Res.* 48, 737. doi:10.1071/SR09155

Kaine, G., Young, J., Lourey, R., and Greenhalgh, S. (2017). Policy choice framework: Guiding policy makers in changing farmer behavior. *Ecol. Soc.* 22, art2. doi:10.5751/ES-09135-220202

Kamil, M. (2020). "The policy processes of agricultural land protection for sustainable food Sovereignty," in Proceedings of the 1st international conference on environmental governance, ICONEG 2019, Makassar, South Sulawesi, Indonesia, October 25–26, 2019 (Makassar, Indonesia: EAI). doi:10.4108/eai.25-10-2019.2300488

Kuang, B., Han, J., Lu, X., Zhang, X., and Fan, X. (2020). Quantitative evaluation of China's cultivated land protection policies based on the PMC-Index model. *Land Use Policy* 99, 105062. doi:10.1016/j.landusepol.2020.105062

Lambert, D. M., Sullivan, P., Claassen, R., and Foreman, L. (2007). Profiles of US farm households adopting conservation-compatible practices. *Land Use Policy* 24, 72–88. doi:10.1016/j.landusepol.2005.12.002

Li, Q. D., Wang, Q. B., Qian, F. K., Liu, H. B., and Zou, Z. H. (2010a). Analysis on the fragmentation of farmers' cultivated land management -- Taking Changtu County of Liaoning Province as an example. *Guangdong Agric. Sci.* 37, 230–232. doi:10.16768/j.issn.1004-874x.2010.06.115

Li, R. Y., and Chen, Y. J. (2017). Study on the protection and utilization behavior of farmers' cultivated land in typical black soil area of Northeast China -- Based on the empirical analysis of farmers' survey in Suihua City, Heilongjiang Province. *J. Agrotech. Econ.* 8, 80–91. doi:10.13246/j.cnki.jae.2017.11.008

Li, X. Y., Zhao, G. M., and Li, B. Y. (2010b). Analysis of land resources change in Northeast China. *Res. Soil water conservation* 17, 68–74.

Liu, B. Y., Zhang, G. L., Xie, Y., Shen, B., Gu, Z. J., and Ding, Y. Y. (2021). Delineating the black soil region and typical black soil region of northeastern China. *Chin. Sci. Bull.* 66, 96–106. doi:10.1360/tb-2020-0178

Lynch, L., Hardie, I., and Parker, D. (2002). *Analyzing agricultural landowners' willingness to install streamside buffers*. Maryland: Department of Agricultural and Resource Economics.

Lynne, G. D., Shonkwiler, J. S., and Rola, L. R. (1988). Attitudes and farmer conservation behavior. *Am. J. Agric. Econ.* 701, 12–19. doi:10.2307/1241971

MacKinnon, D. P., Fairchild, A. J., and Fritz, M. S. (2007). Mediation analysis. *Annu. Rev. Psychol.* 58, 593–614. doi:10.1146/annurev.psych.58.110405.085542

Madarász, B., Jakab, G., Szalai, Z., Juhos, K., Kotroczó, Z., Tóth, A., et al. (2021). Long-term effects of conservation tillage on soil erosion in central europe: A random forest-based approach. *Soil Tillage Res.* 209, 104959. doi:10.1016/j.still.2021.104959

Mann, S. (2018). Conservation by innovation: What are the triggers for participation among Swiss farmers? *Ecol. Econ.* 146, 10–16. doi:10.1016/j.ecolecon.2017.09.013

Mbaga-Semgalawe, Z., and Folmer, H. (2000). Household adoption behaviour of improved soil conservation: The case of the north pare and west usambara mountains of Tanzania. *Land Use Policy* 17, 321–336. doi:10.1016/S0264-8377(00)00033-8

Molnar, J. J. (1985). Farmland protection as a community development issue: Alabama farmer and landowner perspectives. *J. Soil Water Conservation* 40, 528–531.

Nguyen, T., Cheng, E., and Findlay, C. (1996). Land fragmentation and farm productivity in China in the 1990s. *China Econ. Rev.* 7, 169–180. doi:10.1016/S1043-951X(96)90007-3

Ntihinyurwa, P. D., de Vries, W. T., Chigbu, U. E., and Dukwiyimpuhwe, P. A. (2019). The positive impacts of farm land fragmentation in Rwanda. *Land Use Policy* 81, 565–581. doi:10.1016/j.landusepol.2018.11.005

Ntihinyurwa, P. D., and Vries, W. T. de (2021). Farmland fragmentation, farmland consolidation and food security: Relationships, research lapses and future perspectives. *Land* 10, 129. doi:10.3390/land10020129

Ntshangase, N. L., Muroyiwa, B., and Sibanda, M. (2018). Farmers' perceptions and factors influencing the adoption of No-till conservation agriculture by small-scale farmers in zashuke, KwaZulu-natal province. *Sustainability* 10, 555. doi:10.3390/su10020555

Pedersen, A. B., Nielsen, H. O., Christensen, T., and Hasler, B. (2012). Optimising the effect of policy instruments: A study of farmers' decision rationales and how they match the incentives in Danish pesticide policy. *J. Environ. Plan. Manag.* 55, 1094–1110. doi:10.1080/09640568.2011.636568

Sheeder, R. J., and Lynne, G. D. (2011). Empathy-Conditioned Conservation: "Walking in the Shoes of Others" as a Conservation Farmer. *Land Econ.* 87, 433–452. doi:10.3368/LE.87.3.433

Schieffer, J., and Dillon, C. (2015). The economic and environmental impacts of precision agriculture and interactions with agro-environmental policy. *Precis. Agric.* 16, 46–61. doi:10.1007/s11119-014-9382-5

Shaw, D. J. (1963). The problem of land fragmentation in the mediterranean area: A case study. *Geogr. Rev.* 53, 40–51. doi:10.2307/212807

Sheeder, R. J., and Lynne, G. D. (2011). Empathy-conditioned conservation: "Walking in the shoes of others" as a conservation farmer. Available at: http://le.uwpress.org/content/87/3/433.short (Accessed February 19, 2022).

Supalla, R. (2003). Institutional arrangements to improve water quality in irrigated agriculture 1. *Int. J. Water Resour. Dev.* 19, 89–99. doi:10.1080/713672721

Tran, T. Q., and Vu, H. V. (2019). Land fragmentation and household income: First evidence from rural Vietnam. *Land Use Policy* 89, 104247. doi:10.1016/j.landusepol.2019.104247

Traoré, N., Landry, R., and Amara, N. (1998). On-Farm adoption of conservation practices: The role of farm and farmer characteristics, perceptions, and health hazards. *Land Econ.* 74, 114–127. doi:10.2307/3147217

Van den Berg, M. M., Hengsdijk, H., Wolf, J., Van Ittersum, M. K., Wang, G., and Roetter, R. P. (2007). The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. *Agric. Syst.* 94, 841–850. doi:10.1016/j.agsy.2006.11.010

Van Hung, P., MacAulay, T. G., and Marsh, S. P. (2007). The economics of land fragmentation in the north of Vietnam. *Aust. J. Agric. Resour. Econ.* 51, 195–211. doi:10.1111/j.1467-8489.2007.00378.x

Vignola, R., Koellner, T., Scholz, R. W., and McDaniels, T. L. (2010). Decision-making by farmers regarding ecosystem services: Factors affecting soil conservation efforts in Costa Rica. *Land Use Policy* 27, 1132–1142. doi:10.1016/j.landusepol.2010.03.003

Wan, G. H., and Cheng, E. (2001). Effects of land fragmentation and returns to scale in the Chinese farming sector. *Appl. Econ.* 33, 183–194. doi:10.1080/00036840121811

Wang, Z., Liu, L., Chen, Q., Wen, X., and Liao, Y. (2016). Conservation tillage increases soil bacterial diversity in the dryland of northern China. *Agron. Sustain. Dev.* 36, 28. doi:10.1007/s13593-016-0366-x

Wen, Z. L., and Ye, B. J. (2014). Analyses of mediating effects: The development of methods and models. *Adv. Psychol. Sci.* 22, 731–745. doi:10.3724/sp.j.1042.2014.00731

Wilson, G. A. (1997). Factors influencing farmer participation in the environmentally sensitive areas scheme. *J. Environ. Manag.* 50, 67–93. doi:10.1006/jema.1996.0095

Wu, Y. H. (2018). *Analysis of farmers' awareness of cultivated land protection and its influencing factors. Master*. Guangdong Province: Jinan University.

Xiang, Y. (2010). "Farmland System,Farmland scale management and agricultural growth——an empirical study from Heilongjiang province," in 2010 Second International Conference on Communication Systems, Networks and Applications, Hong Kong, China, 29 June 2010 - 01 July 2010 (IEEE), 85–88. doi:10.1109/ICCSNA.2010.5588933

Yadav, D., Vishwakarma, A. K., Sharma, N. K., Biswas, A. K., Ojasvi, P. R., Kumar, D., et al. (2021). Sustaining the properties of black soil in Central India through crop residue management in a conservation-agriculture-based soybean–wheat system. *Land Degrad. Dev.* 32, 2906–2921. doi:10.1002/ldr.3891

Yan, B., Zhang, Y., Zang, S., Chen, Q., and Sun, L. (2021). Distributions of particle sizes in black soil and their environmental significance in northeast China. *Sustainability* 13, 3706. doi:10.3390/su13073706

Yu, H. R., Wang, Y. Z., Liang, Z., and Min, C. K. (2021). The construction of regional ecological security pattern based on a multi-factor comprehensive model and circuit theory. *NEPT* 20, 19. doi:10.46488/NEPT.2021.v20i03.019

Yu, S., Li, G., and Ran, R. P. (2014). Analysis of influencing factors of farmers' cultivated land protection behavior in Karst Area Based on logistic ISM model. *Geogr. Geogr. Inf. Sci.* 30, 140–144+149. doi:10.3969/j.issn.1672-0504.2014.03.029

Zhang, S., Li, Q., Zhang, X., Wei, K., Chen, L., and Liang, W. (2012). Effects of conservation tillage on soil aggregation and aggregate binding agents in black soil of Northeast China. *Soil Tillage Res.* 124, 196–202. doi:10.1016/j.still.2012.06.007

Zhao, H. F., Zhang, F. R., Jiang, G. H., Xu, Y. Q., and Xie, Z. D. (2008). Analysis of the dilemma of arable land conservation in Beijing suburbs based on farmer surveys. *China Land Sci.* 28, 33. doi:10.3969/j.issn.1001-8158.2008.03.004