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Does Land Approval Facilitate Conservation Tillage? An Examination through the Lens of Straw-Returning Technology

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Abstract: Well-defined and stable property rights play a pivotal role in shaping human economic behavior by averting the tragedy of the commons. This study employs micro-survey data from Heilongjiang Province, China, to empirically investigate the impact and mechanisms of land approval on the adoption of straw-returning technology by farmers. Utilizing the Probit model and mediation and moderation effect testing methods, the findings reveal the following: (1) Land approval significantly promotes the adoption of straw-returning techniques by farmers, with a marginal effect of 0.288. This view is further validated through counterfactual inference constructed using the propensity score matching method. (2) Endowment effects mediate the relationship between land approval and farmers' adoption of straw-returning technology. (3) Digital skills and farming scale negatively moderate the policy's impact on farmers' adoption of straw-returning technology. (4) In terms of control variables, the age of farmers and the dispersion of cultivated land have a significant negative impact on the adoption of straw-returning technology by farmers, while training related to agricultural straw-returning skills and government technology promotion significantly positively affects the use of straw-returning technology by farmers. Therefore, the clarity of land property rights helps to harness the policy effects of land approval and provides a research approach for countries with communal land ownership to implement actions for soil quality conservation.

Keywords: land approval; straw-returning technology; endowment effect; conservation tillage

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1. Introduction

Food security is of paramount importance to global sustainability and human well-being. Arable land serves as the cornerstone of food production, but the long-standing, high-intensity agricultural production model has resulted in severe land degradation [1]. Alarming statistics reveal that nearly one-third of the world's land has suffered degradation, presenting one of the most pressing challenges to global food security [2]. The quality of arable land is pivotal for land productivity and national food security. Consequently, preserving and enhancing arable land quality have gradually evolved into critical strategic objectives for stabilizing the agricultural foundation and achieving sustainable agricultural development worldwide [3,4]. China, a significant grain importer and exporter, shoulders the responsibility of sustaining nearly 20% of the world's population with only 9% of the world's arable land. This underscores China's profound role in combating hunger, realizing the United Nations' ambitious 2030 sustainable development goals, and upholding global food security [5]. Black soil refers to land dominated by black or dark black humus as the primary surface material (Chinese Academy of Sciences. https://www.cas.cn/zt/kjzt/htlc/mtbd/202112/t20211227_4819755.shtml, accessed on 18 April 2024). Globally, black soils are mainly concentrated in Northeast China, the Mississippi River Basin in North America, and the Ukrainian plains, playing an important role in ensuring global food security. The northeastern region of China stands as one of the world's three major black soil regions, boasting a total arable land area of approximately 278 million mu (about 18.5 million hectares). Within this region, Heilongjiang Province, accounting for a substantial 56.1% of the total, has consistently secured the top rank in China's total grain production for 13 consecutive years, making it a linchpin in ensuring China's food security and societal stability as of 2022 [6]. Nonetheless, the prolonged focus on production-oriented development models has precipitated the rapid deterioration of black soil quality. Issues such as soil compaction, dwindling soil fertility, farmland pollution, and impaired ecological functions have become increasingly prevalent, leaving the black soil layer progressively "thinner, leaner, and harder" [7]. This has raised significant concerns regarding arable land quality [8,9].

Conservation tillage techniques offer a suite of ecological, economic, and social benefits [10,11]. They can enhance soil physical and chemical properties, elevate soil fertility, and improve the ecological milieu of farmland. Simultaneously, they promote increased crop yields, labor efficiency, and the transition of agriculture toward sustainability [12,13]. Despite this, some scholars still question the effectiveness of conservation farming techniques. For instance, Rosa-Schleich believes that while cover crops provide ecological benefits, they impose high production costs on farmers, putting them at an economic disadvantage [14]. Teklewold argues that implementing conservation farming techniques requires the application of herbicides (such as glyphosate) to kill weeds before planting crops with reduced or no tillage, which could have adverse environmental impacts [15]. While we recognize that no technology can completely solve all problems for farmers, since the introduction of conservation farming techniques in the 1960s, these technologies have been highly regarded by the Chinese government, which has increased policy and financial support to promote their application and nationwide adoption [16,17]. Thus, we align with the mainstream academic view that the benefits of conservation farming outweigh its drawbacks, and we do not consider it a controversial issue worth debating. Based on this, we believe conservation farming is a typical intertemporal benefit of agricultural technology, where current investments yield returns over multiple future periods [18]. Farmers are the basic units of agricultural production, the final decision-makers on adopting agricultural technologies, and direct beneficiaries of soil quality protection [19]. Farmers are also consumers, and their agricultural production activities are predicated on the premise that these activities can essentially meet their survival needs [20]. Therefore, even though farmers might subjectively want to take land protection measures, the lack of family resources (such as labor and capital) forces them to focus on immediate benefits when dealing with daily family expenses (such as daily consumption, social obligations, children's education, etc.) or in the event of sudden large expenses. Especially for low-income groups with relatively scarce material resources, the survival conditions of living and working in agriculture inevitably lead to short-sighted behavior among farmers [21]. However, farmers often exhibit "myopic" tendencies in their intertemporal technology choices, resulting in inadequate demand and enthusiasm for the adoption of conservation tillage technology [22,23]. This circumstance presents a significant obstacle to the widespread embrace of conservation tillage technology. In the current landscape, gaining a deeper understanding of farmers' adoption behavior and the motivating factors behind their decisions concerning conservation tillage technology is imperative for achieving the sustainable utilization of arable land in the northeastern region and protect both China's and global food security.

In a broad sense, conservation tillage technology encompasses a comprehensive array of techniques designed to safeguard the ecological environment of farmland while enhancing agricultural productivity [24]. Its foundational methodologies encompass straw return, reduced or no-tillage practices, deep loosening, and integrated pest and disease control [25].

Previous research predominantly centers on the analysis of farmers' inclinations, behavioral attributes, and the determinants influencing the adoption of conservation tillage. The first two aspects typically commence with assessing the technology's adoption impacts and the disparities between farmers' intentions and actions. Concerning the adoption impacts, investigations reveal that farmers generally exhibit low adoption rates, abbreviated adoption durations, and limited enthusiasm for subsequent adoption stages [26–29]. Regarding the disconnect between farmers' intentions and actions, research suggests the existence of group disparities. Farmers with heightened awareness and positive perceptions are less prone to this divergence [30]. Enhancements in resource endowments, responsibilities, ecological awareness, and favorable attitudes can, to some extent, narrow this gap and promote the implementation of conservation tillage technology [28,31]. Influential factors encompass individual characteristics, familial attributes, resource endowments, regional attributes, and fundamental determinants [8,9,13]. External elements, such as government subsidies and policy incentives [32], also exert influence. The merits, potential risks, as well as cost comparisons, associated with conservation tillage technology significantly influence farmers' intentions and behaviors related to adoption (e.g., the scope and duration of technology integration) [33]. As a crucial component of conservation farming, straw returning involves covering the soil permanently with crop straws and stubbles [34], which helps reduce surface erosion and nutrient loss, while also enhancing soil enzyme activity, promoting the activity of soil microbes, increasing total organic carbon content in the soil [35], and effectively reducing the demand for chemical fertilizers. This, in turn, diminishes the reliance on chemical fertilizers, rendering straw return an effective technique for augmenting soil quality [36].

Land approval refers to the government's establishment of secure land contractual relationships with farmers through the execution of land contracts and the issuance of land contract certificates [37,38]. In rural China, land is collectively owned by village collectives, and various entities possess land use rights. Land property rights, in this context, are inherently ambiguous and unstable, representing a form of public property rights [39]. Under the framework of public property rights, individuals lack control over others' actions and are unable to prevent unauthorized land usage. This ambiguity complicates the perception of land as private property for land users [40]. According to Hardin's theory, unclear property boundaries in public resource management can lead to overexploitation and the pursuit of individual interests, ultimately resulting in resource depletion and the tragedy of the commons. Typically, this tragedy is averted through government regulations or the privatization of public resources [41]. In China, land approval does not equate to land privatization. Instead, it grants farmers a legal concept known as usufructuary rights. Throughout the contract duration, farmers enjoy quasi-permanent usage rights, effectively transforming the land into "property with an owner." This clear property arrangement objectively constrains village organizations from engaging in rent-seeking behaviors, land requisition, and adjustments. Consequently, it safeguards farmers' exclusive rights to utilize, possess, and derive income from the land. Considering long-term interests, the clarity of property rights motivates farmers to prioritize investments in land preservation, thereby promoting the sustainable utilization of agricultural land.

The foundation of land protection lies in the anticipation of future land output revenue [42]. The greater the stability of land rights, the more inclined farmers become to implement land protection measures [43,44] and to boost their investments in the adoption of conservation tillage practices [45,46]. To date, existing research has primarily focused on the impact of land approval on farmers' decisions related to land transfer behavior [47–49], with few studies delving into the relationship between land approval and the adoption of conservation farming techniques. Unlike other commodity transactions, the multifunctional attributes of agricultural land determine that farmers have an emotional and survival dependence on the land, especially in the current context of increasingly loose human–land relationships. Farmers who have the right to transfer land (The 'Measures for the Management of Rural Land Contractual Management Right Transfer' issued by the

Ministry of Agriculture and Rural Affairs of the People's Republic of China on 1 March 2021, stipulates that 'rural land contractual management right transfer (referred to as land transfer) refers to the act whereby the contracting party, under the premise that the contractual relationship between the contractor and the contract issuer remains unchanged, lawfully transfers part or all of the land management rights to another party for a certain period to independently conduct agricultural production and management.' exhibit a "land-treasuring" behavior—they are reluctant to give up their land contracting rights [50]. Consequently, it is imperative to discern whether the latest round of land approval will reinforce farmers' "land conservation" tendencies and whether this specific sentiment will encourage farmers to prioritize land quality preservation and the adoption of conservation tillage techniques. Consequently, it is critical to elucidate the theoretical framework and pathways linking farmland tenure with farmers' land quality preservation behavior, using straw return as an illustration to clarify the relationship between farmland tenure and the adoption of conservation tillage techniques. Further investigation into whether property rights clarity fosters farmers' "land conservation" inclinations bears substantial theoretical and practical significance in comprehending farmers' motivations and adoption behavior concerning land quality preservation decisions.

The organizational structure of the remaining sections in this paper is as follows:

Section 2 will furnish a succinct overview of the theoretical framework and research hypotheses. Section 3 will provide a concise elucidation of the data sources, variable selection, and model setup. Section 4 will comprehensively present the empirical findings of the study and undertake a thorough analysis. Finally, Sections 5 and 6 will encapsulate the research findings and proffer pertinent policy recommendations.

2. Theoretical Analysis

2.1. Land Approval and Farmers' Adoption of Straw-Returning Technology

Straw-returning technology is characterized by its typical intertemporal benefit properties, featuring a prolonged action period and gradual, long-term benefits. As farmers with bounded rationality, the willingness and behavior of adopting straw-returning technology largely depend on whether they can secure all future outputs from the cultivated land [42]. Clear and well-defined property rights serve as the fundamental prerequisite for establishing rights and responsibilities and distributing benefits [51]. The recent round of land approval certification has transformed the previously ambiguous, unstable, and insecure state of land property rights in rural China. It has redefined land within the lease period, shifting it from its prior ambiguous status as public property to a form akin to "private property", exclusively held by farmers. This transformation fulfills farmers' assertions of residual rights and long-term control over their land. The research underscores that unclear land property rights and insecure land tenure are major factors contributing to short-term and exploitative farming practices by farmers [52]. Transparent and secure property rights contribute significantly to incentivizing property ownership and stabilizing farmers' long-term production and investment expectations [53,54]. Some studies have indicated that farmers who have undergone land adjustments often harbor skepticism regarding the security of their land rights, leading to a negative disposition toward land preservation [55]. Conversely, extended land tenure and lease periods tend to align land use and land quality preservation behaviors of transferred land with those of owned land [56]. In comparison to other farmers, those possessing formal land approval certificates generally exhibit heightened land investment behavior [57]. Therefore, property rights incentives play a crucial role in reducing short-term behaviors, reinforcing long-term expectations for land investment, alleviating farmers' apprehensions regarding potential land-related risks, and enhancing enthusiasm for long-term land investment [58]. In summary, land approval serves as the linchpin for clearly defining and demarcating the boundaries of power and income distribution related to land property rights. This preserves farmers' control over land and their expectations of future income from land use and long-term investment. As an agricultural technology entailing intertemporal benefits, straw-returning technology necessitates the prerequisite of complete land property rights and the assurance of obtaining future income for rational smallholders to engage in conservation tillage. Land approval establishes the foundation for solidifying and ensuring the exclusivity of property rights. Building upon this, the paper proposes the following research hypothesis:

Hypothesis 1: *Land approval promotes the adoption of straw-returning technology among farmers.*

2.2. Mediating Effect of Endowments on the Relationship between Land Approval and Farmers' Adoption of Straw-Returning Technology

Thaler's perspective introduces the endowment effect as a phenomenon wherein individuals tend to assign a higher value to an item once they own it, compared to their valuation when they do not possess it [59]. Although this theory might not consider the broader social and economic context [60]—for example, the tendency to 'plunder' when one possesses something—and may even seem somewhat outdated, collective values, social norms, and particularly the multifunctional social security roles of agricultural land, as well as farmers' inherent emotional dependency on it, all contribute to some extent to the increased value farmers place on their land. For instance, in modern agriculture, as the relationship between people and land loosens, farmers with the right to transfer land exhibit 'land-treasuring' behavior—reluctant to give up their land contracting rights [50]. Land, distinct from regular commodities, possesses unique attributes due to the traditional agrarian way of life in which agriculture and land serve as the central pillars [61]. It functions as a crucial resource supporting various dimensions of farmers' livelihoods, encompassing economic sustenance, social security, and emotional attachment [62]. The formalization of land rights through land approval stabilizes farmers' identity and control over the land. This transformation essentially positions farmers as potential "owners" of the land. The land's role in providing livelihood security and the emotional attachment that individuals subjectively associate with it foster a sense of "relative ownership" among farmers. Consequently, they tend to assign greater value to their own land, often exceeding its market worth. This overvaluation tends to discourage short-term practices and inclines farmers toward meticulous land management and long-term investment in its productivity. In essence, land approval enhances the personal property characteristics of land, thereby intensifying the endowment effect [63]. This heightened endowment effect encourages farmers to manifest a more pronounced "land-cherishing" behavior, motivating them to undertake measures aimed at preserving farmland quality. In contrast to short-term and exploitative practices, initiatives like straw return are perceived as long-term investments contributing to the sustainable utilization of land resources. Therefore, from the perspective of the endowment effect, land approval, by augmenting farmers' perceived value of their land, actively prompts them to embrace measures for farmland quality preservation. Building upon this rationale, the research hypothesis is formulated as follows:

Hypothesis 2: *The endowment effect mediates the relationship between land approval and the adoption of straw-returning technology among farmers.*

2.3. The Moderating Effect of Digital Skills on the Relationship between Land Approval and the Adoption of Straw-Returning Technology among Farmers

Drawing from Ren et al.'s research, digital skills can be understood as a comprehensive reflection of various abilities, encompassing proficiency in operations, information navigation, and creativity [64]. However, given the distinctive demographic composition in rural China, this study specifically defines digital skills as an individual farmer's capacity to address challenges using electronic devices. Enhancing digital skills plays a pivotal role in bridging the digital divide and breaking down information barriers. Research indicates that individuals with higher levels of digital skills generally exhibit superior performance in both work and learning [65,66]. During our survey, we observed that despite promotional efforts by village organizations, some farmers still grapple with a degree of ambiguity concerning the concept and advantages of straw-returning technology. The rapid advancement of information and communication technology has granted farmers convenient access to smartphones and computer tools for conducting keyword-based text searches. Through these searches, farmers can access a wealth of information about straw returning, facilitating information comparisons. This process contributes to enhancing farmers' objective and rational comprehension of straw returning, mitigating the risk of subjectively undervaluing the potential benefits of this technology due to a lack of information. Additionally, it serves as a means to compensate for the limitations arising from insufficient promotion by rural government entities. Hence, farmers with elevated levels of digital skills are more inclined to acquire technical information by cross-referencing multiple information sources. They are better equipped to objectively grasp the comprehensive advantages of straw-returning technology and make more judicious value assessments. Conversely, farmers with lower levels of digital skills might exhibit greater reluctance to embrace new technologies. In essence, enhancing farmers' digital skills not only dismantles barriers arising from information asymmetry but also elevates their awareness and comprehension of novel technology. Consequently, this boosts their willingness to accept and adapt to straw-returning technology, motivating more proactive adoption. Building upon this rationale, the study posits the following research hypothesis:

Hypothesis 3: *Digital skills have a negative moderating effect in the relationship between land approval and the adoption of straw-returning technology. That is, digital skills positively influence farmers' adoption of straw-returning technology, and digital skills also weaken the impact of land approval on the adoption of this technology by farmers.*

2.4. The Moderating Effect of Farming Scale on the Relationship between Land Approval and the Adoption of StrawReturning Technology

Straw-returning technology often fails to demonstrate short-term effectiveness [67]. Farmers' decisions regarding technology adoption are contingent on striking a balance between the current utility and future utility of the technology [68]. Concerning the adoption of intertemporal agricultural technology, farmers of varying scales exhibit notable disparities in time preferences [18]. Research suggests that distinct discount rates lead to divergent profit expectations, culminating in group disparities in farmers' technology adoption behavior [69]. Individual time preferences exert a substantial influence on their technology adoption behavior [70]. These time preferences notably diminish farmers' willingness to embrace environmentally friendly technologies. Over time, individual time preferences tend to display relative stability [71], indicating that they remain relatively constant when compared to other farmers. The lack of material resources, high costs of food safety, and the need to support children's education, social obligations, and healthcare might increase small-scale farmers' preference for immediate benefits over future welfare [21,72]; thus, they might prefer to use well-established production methods and technologies like fertilizers and pesticides that yield immediate returns. Existing research underscores the evident ecological and economic advantages of straw-returning technology, including soil improvement, enhanced soil fertility, improved agricultural production environments, the promotion of sustainable agriculture, reduced production costs, and diminished fertilizer use. In contrast to small-scale farmers, large-scale farmers implementing straw-returning technology enjoy economies of scale. They exhibit lower discount rates when adopting long-term environmentally friendly agricultural technology, prioritizing long-term benefits over immediate gains [18]. This implies a greater degree of patience in their choices regarding intertemporal technology adoption. Furthermore, the expansion of the production scale can mitigate the inhibitory impact of time preferences on farmers' technology adoption [73]. Consequently, larger-scale farmers are more inclined to invest in long-term land quality preservation and are more amenable to adopting straw-returning technology. On the basis of this analysis, the following research hypothesis is postulated:

Hypothesis 4: *Farming scale exerts a negative moderating effect on the relationship between land approval and the adoption of straw-returning technology.*

3. Materials and Methods

3.1. Data Source

The data for this study were gathered through a random household survey conducted in specific counties (towns) within Heilongjiang Province, China, in July 2023. To investigate the influence of land approval on farmers' land conservation behaviors, this study undertook a random household survey encompassing farmers in selected counties (towns) within Heilongjiang Province. Throughout the research process, strict adherence to the principles of random sampling was maintained. The sampling procedure encompassed two stages. In the initial stage, sample areas (counties or towns) were chosen randomly. In the subsequent stage, 2–3 natural villages were randomly selected within the chosen areas, and 20–30 households from these villages were randomly designated as the sample group. The selected households encompassed farmers with diverse scales of landholding, including small-scale self-cultivating farmers and large-scale land leaseholders. These farmers predominantly cultivated maize and soybeans. The entire survey was conducted through one-on-one face-to-face interviews by trained researchers who were responsible for completing, screening, and processing the entire questionnaire. Ultimately, a total of 516 questionnaires were collected, of which 480 were deemed valid, resulting in an effective questionnaire rate of 93.02%. The questionnaire was meticulously crafted to capture an array of information related to the personal characteristics of farmers, family attributes, agricultural production and operational characteristics, as well as external environmental factors.

3.2. Variable Selection

3.2.1. Dependent Variable

In this study, the adoption of straw-returning technology by farmers serves as the dependent variable. The sample of farmers included cultivators of varying scales, mainly comprising those with smaller areas of owned land as well as large holders who both own land and participate in land transfer. A household that has embraced straw-returning technology is designated a value of 1, while a household that has not adopted it is designated a value of 0.

3.2.2. Core Independent Variable

Building upon the research conducted by Zheng and others [74,75], it becomes evident that the issuance of land contracts and management rights certificates assumes a critical role within the realm of land approval. This issuance directly influences the execution of land approval policies and farmers' enthusiasm towards them. For certain farmers, land lacking such certificates may be susceptible to potential reclamation at any given time. The land property rights certificate essentially serves as a tangible entity that can anchor farmers' expectations concerning future land income, thereby motivating them to make long-term investments in the land. Consequently, the issuance of land property rights certificates is employed as an independent variable in this study to enhance the precision of measuring the efficacy of land approval policies.

3.2.3. Mediating Variables

The endowment effect is introduced as a mediating variable in the relationship between land approval and farmers' adoption of straw-returning technology. Scholars commonly employ the ratio or difference between willingness to accept (WTA) and willingness to pay (WTP) to gauge the endowment effect, with the former being more prevalent due to its superior capacity for mitigating scale effects [76]. Drawing inspiration from the approach pioneered by Hu and others [77], a double-scenario assumption was incorporated into the questionnaire design. Questions such as "How much rent per mu (WTA) would you expect if you wanted to lease out this land?" and "How much land rent per mu (WTP) would you expect if you wanted to transfer to land of equivalent quality?" were devised. The WTA/WTP ratio was then computed to evaluate different forms of the endowment effect [78]. A ratio greater than 1 signifies the presence of the endowment effect, while a ratio less than or equal to 1 suggests an absence of the endowment effect.

3.2.4. Moderator Variables

Farmers' digital skills were assessed using a five-point Likert scale. This scale included questions related to their ability to utilize the basic functions of a mobile phone, proficiency in using smartphone apps, and competence in searching or browsing agricultural production information on their phones or computers. Values from 1 to 5 represent "completely disagree", "mostly disagree", "neutral", "mostly agree", and "completely agree", respectively, used to assess the digital skills of farmers, serving as moderator variable 1. Based on existing research [22,65], this paper considers the total area of family-operated cultivated land in 2022 as moderator variable 2.

3.2.5. Control Variables

Consistent with prior research [32,33,35], this study predominantly encompasses individual and household characteristics of farmers as well as agricultural production management characteristics. These factors encompass gender, age, health status, educational attainment, political affiliation, village-level roles, off-farm employment, the number of agricultural laborers within the household, the presence of a family member holding a village cadre position, and participation in agricultural production-related training. Additionally, it incorporates variables related to agricultural production management, such as the extent of land fragmentation and the possession of agricultural insurance. External environmental factors, including proximity to the nearest township, crop yield reduction attributable to natural disasters in 2022, and the level of awareness regarding straw mulching policies, are also taken into account as control variables. Definitions and descriptive statistics for these variables can be found in Table 1.

Table 1. Variable definitions and descriptive statistics.

Variable Name		Definition	M	SD
Straw-Returning Technology		Whether the straw-returning technology is adopted: Yes = 1, No = 0	0.338	0.473
Land Approval		Whether they have received the new round of land approval: Yes = 1, No = 0	0.283	0.451
Endowment Effect		Whether the WTA/WTP ratio is greater than 1: Yes = 1, No = 0	0.554	0.498
Digital Skills		The arithmetic mean of the ability to collect and analyze information using electronic products such as mobile phones and computers.	2.383	1.336
Farming scale		Total cultivated land area in the family for the year 2022	117.4	169.2
Individual Characteristics	Gender	Male = 1, Female = 0	0.825	0.38
	Age	Actual age of the farmer	54.48	10.1
	Health Condition	Relative health condition compared to peers: Very Poor = 1, Poor = 2, Fair = 3, Good = 4, Very Good = 5	4.06	0.998
	Education Level	Primary school or below = 1, Junior high school = 2, Senior high school or technical school = 3, College and above = 4	1.792	0.796
	Political Affiliation	Non-partisan = 0, Partisan = 1	0.129	0.336
	Village Position	Ordinary villager = 0, Other = 1	0.171	0.377
	Off-farm Employment Status	Ratio of the number of off-farm workers to the total labor force	0.133	0.246

Table 1. *Cont.*

Variable Name		Definition	M	SD
Family Characteristics	Agricultural Labor Force	Actual number of individuals engaged in agricultural production in the family	1.704	0.838
	Village Leadership	Whether someone in the family holds a village leadership position: Yes = 1, No = 0	0.146	0.353
	Agricultural Production Training	Whether someone in the family has received agricultural production-related training: Yes = 1, No = 0	0.233	0.423
Production and Operation Characteristics	Degree of Land Fragmentation	Centralized and contiguous = 1, Close proximity and dispersed = 2, Distant and dispersed = 3	2.265	0.683
	Agricultural Insurance	Whether agricultural insurance is purchased: Yes = 1, No = 0	0.708	0.455
External Environmental Characteristics	Distance	Distance in kilometers from the residence to the nearest township	6.471	4.799
	Natural Disasters	Whether there was a yield reduction due to natural disasters in 2022: Yes = 1, No = 0	0.377	0.485
	Technology Promotion	Whether there is promotion of the straw-returning technology: Yes = 1, No = 0	0.627	0.484
	Agricultural Subsidy	Agricultural subsidy amount for the year 2022	15,004	42,698

3.3. Model Selection

As the adoption of straw-returning technology by farmers is a binary variable, this study follows established research [9,10] and employs a binary Probit model to evaluate the policy influence of land approval. The model is specified as follows:

$$y = a_0 + a_1 Certif + \sum \beta_i x_i + \varepsilon_1 \quad (1)$$

Here, y represents the adoption of straw-returning technology by farmers, $Certif$ represents the issuance of the new round of land approval, x_i represents the coefficients for control variables across four dimensions: individual characteristics, family characteristics, agricultural production and operation characteristics, and external environmental characteristics. a_0 is the constant term, a_1 is the impact coefficient of land approval, β_i represents the coefficients for the control variables, and ε_1 is the error term.

4. Results

4.1. Analysis of Baseline Regression Results

After conducting the calculations, the overall mean VIF of the model is 1.37, with the highest VIF value among variables being 2.34. This suggests that there is no issue of multicollinearity among the variables in the model, allowing us to proceed with the analysis without concerns about collinearity. In the baseline regression (as presented in Table 2, Model 1), when not considering other variables, it is evident that land approval has a significantly positive impact on farmers' adoption of straw-returning technology. After controlling for other variables (as shown in Model 2 of Table 2), the policy effect of land approval, while somewhat reduced (the marginal effect decreased from 0.434 without control variables to 0.288 with control variables), remains significant and does not undergo substantial changes. This observation suggests that land approval and certification issuance continue to encourage farmers' long-term investment in land and direct adoption of straw returning. As anticipated, land approval clarifies the boundaries of land property and power ownership, consolidating farmers' residual control rights over arable land, and thereby facilitating the adoption of straw-returning technology.

Table 2. Baseline regression and robustness test results.

Variable Name	Model 1		Model 2		Model 3	
	Coefficient	Robust Standard Error	Coefficient	Robust Standard Error	Coefficient	Robust Standard Error
Land Approval	1.543 ***	0.140	1.366 ***	0.176	1.369 ***	0.176
Gender			0.118	0.186	0.121	0.186
Age			−0.021 **	0.008	−0.021 **	0.008
Health Condition			0.126	0.083	0.126	0.083
Education Level			0.079	0.118	0.080	0.118
Political Affiliation			−0.016	0.254	−0.008	0.253
Village Position			−0.001	0.265	0.003	0.264
Off-farm Employment Status			0.284	0.335	0.280	0.335
Agricultural Labor Force			0.035	0.115	0.035	0.116
Leadership			0.102	0.270	0.010	0.270
Agricultural Production Training			0.791 ***	0.186	0.787 ***	0.186
Degree of Land Fragmentation			−0.385 ***	0.12	−0.383 ***	0.12
Agricultural Insurance			0.049	0.182	0.052	0.182
Distance			0.006	0.013	0.004	0.015
Natural Disasters			0.200	0.160	0.199	0.160
Technology Promotion			0.791 ***	0.196	0.794 ***	0.196
Agricultural Subsidy			−0.000	0.000	−0.000	0.000
Constant	−0.914 ***	−0.079	−0.714	0.706	−0.704	0.71
Observations	480		480		480	
p-Value	0		0		0	
R-Squared	0.2151		0.4194		0.4192	

Note: **, *** indicate that the estimated results are significant at the 5% and 1% levels, respectively.

Control variables unveil valuable insights into farmers' adoption of straw-returning technology. Notably, age exerts a negative influence on farmers' willingness to embrace crop straw-returning practices. This implies that older farmers are less inclined to adopt this approach. This tendency may stem from the characteristics of straw returning as a long-term agricultural technology. During its initial stages of implementation, straw decomposition is gradual, nutrient release occurs incrementally, and the immediate benefits, such as increased crop yields and soil enhancement, may not be immediately apparent. Moreover, there's an increased risk of pests, diseases, and weed proliferation, which can lead to diminished yields. Older farmers, who often rely heavily on agriculture for their livelihoods, may lean more towards traditional crop cultivation methods, such as bundling and burning or straw removal from fields, rather than the direct adoption of straw returning. Additionally, older farmers may exhibit a lower receptiveness to new technologies, have reduced risk tolerance, and have a stronger preference for risk avoidance, collectively dampening their enthusiasm for straw-returning technology. Conversely, participation in agricultural production training exerts a positive impact on farmers' adoption of straw-returning technology. Access to training in agricultural production skills plays a pivotal role in challenging traditional mindsets among farmers, thus increasing their willingness to explore straw-returning technology. Another significant factor is the degree of land fragmentation, which wields a notably negative influence on farmers' adoption of straw-returning technology. This suggests that excessive land fragmentation does not favor farmers in making long-term investments in their land. It underscores the importance of consolidated land holdings for the successful adoption of practices like straw returning. Furthermore, technology promotion emerges as a substantial driver of farmers' adoption of straw-returning technology. This finding underscores the pivotal role played by government-led initiatives and promotional campaigns aimed at raising awareness and understanding of the comprehensive benefits associated with straw returning. Government promotion effectively enhances farmers' perception of the overall value of straw returning, thereby motivating their active participation in this practice. Other main control variables, such as farmers' health conditions, education level, and the extent of their side business activities, influenced the expected direction, but not significantly. A healthy physical condition might help farmers adopt straw returning, but since straw-returning technology heavily relies on machinery, health may not be a major factor influencing its adoption. Higher education levels might comprehensively enhance technology understanding [43,79], potentially inhibiting the adoption of straw-returning to some extent. Farmers with a higher degree of side business activities often have a greater capacity to share risks [80,81] and may have better alternative options than straw-returning technology. The variable for the number of agricultural laborers in the household had a positive coefficient but was not significant, possibly because straw returning heavily depends on mechanical operations and does not require much manual labor [80]. The direction of the impact of agricultural insurance was consistent with expectations, but the effect was not significant. This might be because purchasing agricultural insurance helps reduce external risk losses, but nearly every household purchases agricultural insurance (at least according to our survey), enabling them to adopt other land quality protection technologies, not just straw-returning ones. The direction of the impact of agricultural subsidies was inconsistent with expectations, mainly because subsidies for straw-returning technology are primarily targeted at users of straw-returning machinery, lacking incentives for small farmers to adopt the technology [82].

4.2. Mechanism Analysis of the Impact of Land Approval on Farmers' Adoption of Straw-Returning Technology

We used a stepwise regression method to explore the mechanism through which land approval influences farmers' adoption of straw-returning technology; the model estimation results are presented in Table 3. Model 1 provides evidence that land approval has a significantly positive impact on farmers' adoption of straw-returning technology, thus validating the first step of our analysis. Model 2 extends this understanding by revealing that land approval significantly enhances the endowment effect among farmers, confirming the second step of our examination. Model 3 builds on these findings, demonstrating that both land approval and the endowment effect exert a substantial and positive influence on farmers' adoption of straw-returning behavior. This result strongly suggests the presence of a mediating effect, with the endowment effect serving as the mediator in the relationship between land approval and farmers' adoption of straw-returning technology. Specifically, land approval plays a pivotal role in amplifying farmers' overestimation of their land's value, leading to a heightened endowment effect. This amplified endowment effect, in turn, encourages farmers to engage in "land conservation" behaviors, making them more inclined to adopt straw-returning technology. Thus, we can confidently assert that Hypothesis 2 is substantiated by our analysis.

Table 3. Mediation effects (stepwise regression).

Variable Name	Straw Returning	Endowment Effect	Straw Returning
	Model 1	**Model 2**	**Model 3**
Land Approval	1.366 ***	0.545 ***	1.318 ***
	(0.176)	(0.154)	(0.179)
Endowment Effect			0.291 **
			(0.145)
Control Variables	Controlled	Controlled	Controlled
Observations	480	480	480
p-value	0	0	0
R-squared	0.419	0.082	0.425

Note: **, *** indicate significance at the 5% and 1% levels, respectively. Standard errors are shown in parentheses.

To further assess the robustness of the mediation effect analysis, we recognize that the dependent variable is binary, making the Sobel test inappropriate. Instead, we employ the widely recognized Bootstrap resampling method. After conducting 500 repetitions, the estimated results of the bias-corrected indirect effect (_bs_1) and direct effect (_bs_2) are presented in Table 4. Notably, the bias-corrected confidence interval (BC) for the indirect effect significantly differs from zero, providing clear evidence of a mediation effect. This reaffirms that the endowment effect effectively serves as a mediator between land approval and farmers' adoption of straw-returning technology. These results underscore the robustness and reliability of the mediation effect analysis for the variables under consideration.

Table 4. Mediation effect (bootstrap test) estimation results.

	Coefficient	Bias	Standard Error	Confidence Interval		
_bs_1	0.0115	0.0004	0.0074	−0.0002	0.0276	(P)
				0.0001	0.0284	(BC)
_bs_2	0.3926	−0.0023	0.0543	0.2853	0.4948	(P)
				0.2935	0.5026	(BC)

4.3. Moderating Effects of Digital Skills and Farming Scale on the Land Approval Policy Impact

In the baseline model, we introduced digital skills, farming scale, and their interactions with land approval to investigate how digital skills and farming scale moderate the effects of land approval policy. The estimation results are presented in Table 5. In Model 1, both digital skills and land approval are statistically significant at the 1% level, and the interaction term has a negative coefficient that is also significant at the 1% level. This implies that digital skills have a significant negative moderating effect on the influence of land approval on farmers' adoption of straw-returning technology. The use of digital tools, combined with improved digital skills, helps overcome information barriers in rural areas, fostering reasonable expectations about the effects of straw-returning technology. In Model 2, both farming scale and land approval exhibit significant positive impacts on farmers' adoption of straw-returning technology, and the interaction term has a negative coefficient that is statistically significant at the 10% level. This indicates that the farming scale negatively moderates the policy effect of land approval. Hence, under the influence of scale effects, large-scale farming households have a lower discount rate for adopting straw-returning technology. When compared to small-scale farmers, these households are more inclined to implement straw-returning practices. These results provide support for Hypotheses 3 and 4.

Table 5. Estimated moderation effects.

Variable Name	Model 1	Model 2
Land Approval	0.652 ***	1.412 ***
	(0.235)	(0.180)
Digital Skills	0.768 ***	
	(0.135)	
Land Approval * Digital Skills	−0.668 ***	
	(0.221)	
Farming Scale		0.002 ***
		(0.001)
Land Approval * Farming Scale		−0.002 *
		(0.001)
Control Variables	Controlled	Controlled
Observations	480	480
p-Value	0.000	0.000
R-squared	0.540	0.465

Note: *, *** indicate significance at the 10% and 1% levels, respectively. Standard errors are in parentheses.

4.4. Robustness Checks

4.4.1. Outlier Data Removal

To address potential biases introduced by outliers in the data, we applied trimming to some of the continuous variables by capping them at the 1st and 99th percentiles. After this data processing, the model estimates are presented in Table 2, Model 3. The results for the land approval policy effect, following data processing, align with the findings from the baseline regression in Model 2. This consistency underscores the robustness of the conclusions previously discussed. Furthermore, concerning the control variables, age and the degree of land fragmentation continue to exhibit a significantly negative impact on farmers' adoption of straw-returning technology. Conversely, agricultural production training and straw-returning policy promotion maintain their significantly positive impact on farmers' adoption of straw-returning technology. The effects of the remaining variables remain statistically insignificant, consistent with the earlier results and reinforcing their robustness.

4.4.2. Propensity Score Matching

Land approval is a system arrangement initiated and regulated by the state [83]. Although land approval has been implemented across most regions, the issuance of land approval certificates can still vary by area, potentially introducing selection bias among farmers. Therefore, we employ the propensity score matching method based on the Probit model to make counterfactual inferences, stratifying farmers based on whether they have received land approval certificates [78]. Balance tests and common support tests demonstrate that the matched models exhibit strong explanatory power. The estimated treatment effects under various matching methods are summarized in Table 6. The Average Treatment Effect on the Treated (ATT) estimates, obtained through 1:4 nearest neighbor matching, caliper matching, caliper within k-nearest neighbor matching, and kernel matching, all yield significantly positive results. The net effect of land approval is estimated at 0.433, suggesting that, after controlling for systematic differences in the samples, land approval leads to a 43.3 percentage point increase in farmers' adoption of straw-returning technology. This reinforces the robustness of the empirical findings discussed earlier.

Table 6. Estimated Treatment Effects using Propensity Score Matching.

Matching Method	Treatment Group	Control Group	ATT Value	Standard Error	t-Value
Before Matching	0.735	0.180	0.555 ***	0.040	13.63
k-Nearest Neighbor Matching (k = 4)	0.744	0.331	0.414 ***	0.061	6.81
Caliper Matching (Caliper = 0.01)	0.704	0.328	0.376 ***	0.064	5.91
Caliper within k-Nearest Neighbor Matching (k = 4, Caliper = 0.01)	0.704	0.310	0.395 ***	0.059	6.70
Kernel Matching	0.744	0.320	0.425 ***	0.543	7.82
Average			0.433	-	-

Note: *** represent significance at the 1% levels.

5. Conclusions and Discussion

Property rights clarity is fundamental for delineating rights and responsibilities, serving as a crucial means to achieve sustainable resource utilization. In 2023, this study conducted a random sampling survey in Heilongjiang Province, China, employing the Probit model and methods for testing intermediate and moderating effects to derive the following conclusions: Land approval significantly stimulates farmers to adopt straw-returning technology. This highlights the pivotal role of clear and stable land property rights in encouraging farmers to embrace straw-returning practices. Land approval certification acts as a catalyst for reinforcing farmers' endowment effects, motivating them to engage in land resource conservation. Specifically, endowment effects serve as intermediaries in the process of how land approval affects the adoption of straw-returning technology. Digital skills and farming scale exert negative moderating effects on the policy impacts of land approval concerning farmers' adoption of straw-returning technology. The adoption of straw-returning technology correlates closely with various factors, including the age of farmers, the degree of land fragmentation within their families, whether any family member has received agricultural production training, and the extent of government policy promotion. Notably, older farmers and those with more fragmented land holdings exhibit a reduced propensity to implement straw-returning technology. Conversely, agricultural skills training and government technology promotion positively influence farmers' adoption of straw-returning technology. These findings shed light on the multifaceted dynamics of land approval, property rights, digital skills, and other factors influencing the adoption of sustainable agricultural practices by farmers. Farmers are the direct adopters of straw-returning technology, and the government is the direct promoter. To achieve a transformation to conservation farming practices, it is essential to leverage the power of external economic entities (or organizations), such as through land consolidation and land transfer, to fully realize the synergistic benefits among "farmer–government–market" multiple entities.

The concept of collective land ownership inherently implies that, in the absence of clearly defined property boundaries and without intervention in individual behavior, there will inevitably be a dissipation of rents, resulting in economic inefficiency. Following Hardin's theory, government regulations or the privatization of public resources become critical avenues for achieving efficient resource allocation. However, in a country like China, where land is collectively owned in rural areas, the costs associated with land privatization are often exorbitant. Hence, exploring the allocation of exclusive land use, possession, and benefit rights to individual farmers within the framework of collective land ownership represents an effective means of "privatizing" ambiguous public property within a legal context, essentially designating it as "private property". This transformative process effectively converts what was previously considered "unowned" property rights into "owned" property rights. Land approval bestows upon farmers long-term usage rights and all associated rights to the land for the duration of the contract, thereby elucidating farmers' freedom to manage their contracted land. This essentially imbues the land with the characteristics of "private property" for farmers. Grounded in property rights theory, the stability of these property rights and their potential legal interpretation as "ownership" serve to solidify farmers' long-term investment expectations and stimulate their protective behavior toward farmland. This transmission pathway has garnered substantiation in prior studies. In a departure from existing research, this paper adopts a property rights perspective, taking into full consideration the bounded rationality of farmers and the multifaceted attributes of land, including its role in livelihoods and emotional significance. The paper aims to unveil the underlying mechanisms through which land property rights impact farmers' decisions regarding farmland quality protection behaviors, offering valuable practical insights.

6. Recommendations

Based on the research findings mentioned above, the following policy suggestions are presented: First, for countries with communal land ownership, it is essential to clarify land tenure through the process of land approval. During the contracted period, the government should grant farmers exclusive rights to all proceeds generated from the land and restrict other entities from having unrestricted disposal rights over this land. This approach aims to bolster farmers' land approval relationships and stabilize their expectations regarding long-term investments in farmland. Land approval certificates serve as crucial legal property rights documents. Therefore, governments should not only formally define land property rights but also ensure the widespread distribution of land approval certificates. This will help fully realize the policy effects and encourage the adoption of practices such as straw mulching. Second, digital literacy plays a pivotal role in overcoming information barriers and bridging the digital divide. To enhance farmers' capabilities in retrieving online information and address the information gap stemming from insufficient government promotion of straw-returning technology, it is imperative to develop rural digital infrastructure and provide guidance to enhance digital skills. Third, it is necessary to fully consider the characteristics of farmers of different scales and age groups in adopting straw-returning technology and to develop a comprehensive plan that fits specific farmers. For example, for elderly farmers, the demonstration effect of neighborhood trust and village collectives should be leveraged, while the promotional role of mobile apps and digital media should be emphasized for the younger generation. At the same time, village collectives should conduct propaganda and education by regularly organizing learning sessions and training sessions, using village loudspeakers, displaying boards and windows, and even carrying out door-to-door science popularization to gradually guide farmers to adopt straw-returning technology. Additionally, efforts should be made to establish and improve social security systems represented by pension insurance and minimum living guarantees, and gradually expand the scope of straw-returning subsidies recipients (for example, farmers implementing straw returning should be included in the scope of straw-returning subsidies) to fully unleash the potential for investment in rural land quality protection.

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