THE IMPACT OF INFORMATION LITERACY AND ENVIRONMENTAL REGULATIONS ON THE ADOPTION OF CONSERVATION AGRICULTURAL TILLAGE TECHNOLOGIES: NEW EVIDENCE FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT IN SHANDONG PROVINCE OF CHINA

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Abstract. This study takes Shandong province, China as a case to conduct an in-depth analysis of the factors influencing farmers' adoption of conservation agricultural tillage technologies (CATT). It employs the Heckman two-stage model to examine the significant constraints and their relationships, thereby identifying the specific impact effects among various factors. The conclusions as follows: (1) Environmental regulations can positively promote the adoption of CATT. Incentive regulations and constraint regulations both have a significant positive impact on farmers' adoption of CATT except guiding environmental regulations. Farmers with higher information literacy can change traditional production concepts, thereby promoting the adoption of CATT. (2) Farmers' age inhibits the adoption of CATT. The concentrated farmland area is conducive to the application of CATT. Application of CATT services promote farmers' adoption. Agricultural subsidy policies can stimulate farmers' enthusiasm for adopting new technologies; older farmers, however, place greater emphasis on traditional farming methods. Households with more agricultural laborers are less inclined to adopt CATT. Educational attainment also has a positive impact. (3) Incentive-based environmental regulations and guiding environmental regulations can have an indirect impact through information literacy. Constraint-based environmental regulations do not play an intermediary role in farmers' adoption of protective agricultural cultivation techniques.
Keywords: *high-quality agricultural development, information technology, sustainable land management, farm households, ecological environment*

Introduction

High-quality agricultural development means maintaining and managing farm-land ecosystems while making rational and effective use of natural resources (Zafar et al., 2023; Chengot et al., 2024). However, China's agricultural resource development model, characterized by high pollution, high emissions, and low output, has not fundamentally changed over the years, and the phenomenon of "ecological depletion of agricultural production capacity" has become increasingly severe (Yi et al., 2024). As the most fundamental input factor in agricultural production, farmland has begun to exhibit issues such as continuous degradation of soil quality and worsening agricultural non-point source pollution under the dual influences of unregulated human cultivation activities and unreasonable development and utilization. These issues severely hinder agricultural development. In this context, implementing conservation tillage or fallow techniques has

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become an effective measure to address the decline in farmland quality (Mirsky et al., 2012). Conservation tillage is a modern farming technology system primarily involving straw coverage of the soil surface, no-till or reduced-till seeding, deep loosening, and integrated pest, disease, and weed control. Its essence lies in utilizing crop straw to cover the soil surface, thereby improving soil quality and achieving objectives such as increased yields, cost savings, quality improvement, and reduced resource consumption (He et al., 2006; Zentner et al., 1996). In 1934, the United States' western expansion caused severe damage to farmland, triggering the devastating "Dust Bowl" disaster that shocked the world. Subsequently, people began to improve traditional farming methods, and conservation tillage began to emerge. Compared to traditional farming methods, conservation agriculture has two main benefits: first, it reduces emissions of greenhouse gases such as CO_2 and N_2O, as well as water vapor, from the soil, improves soil physical and chemical properties, prevents soil erosion (Subrahmaniyan et al., 2024), and enhances soil fertility; on the other hand, it can reduce the number of times agricultural machinery enters the fields, lower the input of production mate-rials such as fuel and labor, and minimize soil compaction caused by machinery. This plays a crucial role in crop yield increases (Nugroho et al., 2023), making it an important means of farm-land ecological restoration. Although China has introduced multiple relevant policies and provided technical subsidies and other measures to promote and publicize conservation tillage, farmers are still influenced by traditional farming habits and eco-nomic factors, resulting in CATT remaining in a developmental stage and not yet widely adopted. The barriers to the promotion of CATT are based on farmers' low level of understanding and willingness to adopt the technology (Brozovic et al., 2023), and the fact that CATT has a long-term effect and takes time to show results, making it a cross-period agricultural technology. The benefits are sustained returns after initial investment, and farmers who adopt CATT can achieve good ecological and economic benefits. Farmers are the primary beneficiaries of environmentally friendly technologies. Exploring their influence on the adoption of such technologies can help promote sustainable agricultural development. Therefore, how to widely apply CATT in China is of great significance for sustainable development of agricultural.

From an internal perspective, farmers are key participants digital rural development and the implementation of the rural revitalization strategy. The "Digital Rural Development Action Plan (2022-2025)" jointly issued by China and nine other departments outlines the deployment and arrangements for digital rural development, emphasizing the need to enhance farmers' information literacy and skills. This underscores that improving farmers' information literacy has become a critical factor in addressing agricultural development challenges. Digital technology empowers rural revitalization and can drive changes in agricultural production methods by reducing information search costs and enhancing the promotion of agricultural technologies (Yuan et al., 2025; Ma et al., 2025), which also imposes higher requirements on farmers' information literacy. Improving farmers' information literacy not only alters their perceptions and attitudes toward CATT but also effectively promotes their adoption of such technologies (Olorunfemicc, 2024). However, information literacy is not high, and their ability to utilize information technology to participate in CATT is also relatively insufficient, this is primarily due to incomplete information, distrust, and high contextual dependence. The complexity of knowledge lies in the fact that conservation agriculture is a complex system of techniques rather than a single operation. Farmers need to master a series of new skills, including pest and disease management, weed control, and fertilizer

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application adjustments, which entails high learning costs. Information credibility is evident in farmers' greater trust in neighbors and firsthand observed outcomes. Without successful local demonstration cases, or when extension information from research institutions or government agencies is disconnected from local realities, trust is difficult to establish. The uncertainty of long-term effects is evident in the fact that the benefits of conservation agriculture—such as soil improvement and enhanced water retention capacity—typically manifest only after several years. The lack of intuitive, predictable data on long-term returns heightens farmers' concerns about short-term risks and uncertainties. Therefore, studying information literacy impact on farmers' adoption of CATT is of great theoretical significance and practical value, optimizing the promotion and adoption mechanism of green production technology, and advancing the development of green agriculture.

Among external factors, government and market are the key variables influencing farmers' adoption of CATT (Wang et al., 2007). Although CATT possesses positive externalities, its market value is often difficult to directly quantify, and the market trust and regulatory framework remain underdeveloped. The government plays a pivotal role by establishing a systematic policy framework to guide farmers toward a transition to green production through top-down design. Environmental regulations serve as multi-dimensional external incentives, with the core focus on the government utilizing subsidy incentives, penalty measures, and technical training to guide farmers toward making production choices that are both economically efficient and environmentally friendly (Avemegah et al., 2024; Meng et al., 2025). Existing research indicates that different types of environmental regulations have varying impacts on farmer behavior. For example, guiding-type environ-mental regulations promote the adoption of straw mechanical return to fields and green pest control, incentive-type environmental regulations encourage the use of biological pesticides, while constraint-type environmental regulations are effective in promoting the cultivation of disease-resistant varieties. Furthermore, based on Ban-dura's social learning theory and motivation theory, farmers' adoption of CATT is viewed as a complex process where external environmental factors stimulate internal motivational factors. Therefore, exploring the impact of environmental regulations on farmers' adoption of CATT through both internal and external factors can help optimize policy design and promote agricultural green transformation (Qian et al., 2024).

To address the challenge of promoting conservation tillage technology and advance high-quality agricultural development, this study focuses on the interactive effects of internal and external factors. It aims to explore the underlying mechanisms through which information literacy and environmental regulations influence farmers' technology adoption behavior. The study not only examines the direct impact of information literacy as an internal driver but also emphasizes the moderating role of environmental regulations as an external push. This approach seeks to systematically reveal pathways for promoting technology adoption through a dual internal-external approach, providing scientific support for formulating precise and effective agricultural green transition policies.

Literature review

The essence of CATT

Griliches (1957) was one of the first scholars to study the adoption of agricultural technologies, and subsequent research on agricultural technology selection behavior

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and its influencing factors has garnered significant attention from the academic community. In the 1960s, China introduced CATT and began conducting trials and demonstrations. Although the area under conservation tillage has increased year by year, overall, it remains in its infancy. Conservation tillage is an integration of multiple technologies, but in reality, the proportion of farmers adopting the entire CATT system is very small. Among them, the proportion of farmers adopting straw mulching and no-till seeding technologies is relatively high, while the proportion of farmers adopting deep plowing and integrated pest and weed management technologies is relatively low (Ling et al., 2025; Yu et al., 2025). Existing literature has studied farmers' adoption of CATT from different perspectives and in different regions. Tellez-Riocc et al. (2015) confirmed that implementing conservation tillage can effectively control greenhouse gas emissions, inhibit soil and water resource loss, and curb the loss of soil fertility, thereby producing protective effects on the ecological environment. Schipanski et al. (2014) suggest that moderate adoption of conservation tillage measures can enhance soil fertility and agricultural product yields, contributing to the coordinated development of conservation tillage and food security. Marquardt et al. (2019) found that adopting CATT can effectively suppress ecological damage such as soil erosion and water loss, improve the quality standards and market potential of agricultural products, and thereby support farmers' economic development and welfare improvements. Domestic scholars Tong et al. (2023) studied four CATT in the Heilongjiang region and concluded that the currently well-applied conservation tillage models in the region include: straw in-situ coverage no-till seeding, straw row-based no-till seeding, straw strip tillage no-till seeding, and straw minimal coverage no-till seeding. The technologies include: variety selection, deep plowing and loosening, stem and leaf weed control, secondary straw crushing, seedling protection and cultivation, and stubble removal. Compared with traditional tillage methods, CATT can reduce machinery operation costs by 30%–40%, save 40%–50% of labor time, and increase grain yields by 3%–8%. In 2022, Kang (2022) conducted a study on the development of CATT in the Hexi Irrigation District and its impact on soil, concluding that conservation tillage measures (no-till, straw mulching) can improve the physical structure and chemical properties of the soil surface, having a positive impact on soil fertility enhancement and environmental protection.

The impact of information literacy on farmers' adoption of CATT

With the rapid development of modern networks, many studies have begun to focus on the impact of network technology or information-based tools on farmers' adoption of CATT. CATT is an integration of multiple technologies, and as a knowledge-intensive agricultural technology, information resource constraints are a key factor limiting farmers' adoption of this technology (Deng et al., 2023). Compared to urban residents, farmers have fewer channels for obtaining information and are typical information-disadvantaged groups. In agricultural production and management, they primarily rely on personal experience and subjective perceptions, with limited capabilities for collecting, processing, and utilizing information, resulting in severe information lag and distortion (Pei et al., 2025). As the level of rural network infrastructure construction continues to improve, the integration of the internet with the "three rural issues" (agriculture, rural areas, and farmers) has deepened. The introduction of information and communication technology can effectively reduce information search costs and break down information barriers (Shen, 2025; Yan and

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Yan, 2020), thereby promoting farmers' adoption of advanced agricultural technologies. For example, Huang et al. (2022) used a mediation effect analysis method to demonstrate that the use of mobile internet can enhance farmers' ability to obtain information and alter their risk attitudes toward new green technologies, thereby promoting the adoption of green production technologies by farmers; Peng and Yan (2022) reached similar conclusions found that internet use positively influences apple growers' adoption decisions and intensity by enhancing their risk perception capabilities, strengthening their information-gathering abilities, and expanding their social interactions; Jiang et al. (2021) used straw return technology as an example and conducted empirical research within a "counterfactual" analysis framework, finding that internet use does not influence farmers' adoption of straw return technology by increasing their expected economic benefits or reducing their risk perception, but rather by enhancing their expected ecological benefits. Additionally, some scholars have explored the impact of information literacy on farmers' behavior. Some scholars have confirmed that information literacy significantly promotes farmers' engagement in e-commerce operations (Na et al., 2025) adoption of green pest control technologies (Yan and Liu, 2022), purchase of socialized services (Shi and Fu, 2022), and participation in rural governance (Li and Jiang, 2022). The above studies indicate that most scholars hold a positive attitude toward the role of the internet in promoting agricultural production and technology dissemination. However, some studies have found that mobile phones and the internet have not become effective means for farmers to obtain agricultural technology information, which may be related to farmers' lack of proactive ability to search for and obtain agricultural technology information via mobile phones and computers (Hu et al., 2019). Therefore, future efforts should continue to focus on enhancing farmers' capacity to learn and apply advanced information technologies, guiding them to utilize modern information tools to access and learn advanced agricultural technologies, with the aim of improving production efficiency and increasing agricultural income.

The impact of environmental regulations on farmers' adoption of CATT

In recent years, the focus of environmental regulation research has gradually shifted from industrial enterprises to individual farmers. Existing studies have confirmed the promotional role of environmental regulations in farmers' green production behaviors. Among them, Ren and Guo (2023) used survey data from 569 farmers in Shandong Province to empirically demonstrate that environmental regulations can promote farmers' adoption of low-carbon technologies. Zhang et al. (2021) used a logistic model to empirically test the promotional effect of environmental regulations on farmers' adoption of organic fertilizers. Meng et al. (2025) found that environmental regulations have a significant positive impact on the adoption of CATT, enhancing farmers' adoption decisions and adoption levels in black soil regions. Shen et al. (2025) concluded that incentive-based environmental regulations, guiding environmental regulations, and green cognition all have a significant positive impact on farmers' adoption of green production technologies, while restrictive environmental regulations have a negative impact. Xia et al. (2019) found that environmental regulations have a significant positive impact on the willingness of large-scale pig farmers to engage in resource utilization. Xu et al. (2021) found that incentive-based environmental regulations have a significant positive moderating effect on farmers' cognition of agricultural green production policies, their understanding of the hazards of agricultural non-point source pollution, and their

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willingness to adopt green production practices. Constraint-based environmental regulations also have a significant positive moderating effect on farmers' cognition of agricultural green production policies, their understanding of the prospects for agricultural green development, and their willingness to adopt green production practices. It is evident that research on the impact of environmental regulations on farmers' adoption of CATT is urgently needed, and its findings hold profound practical significance for promoting green development in agriculture. Green production behaviors exhibit diverse characteristics, and the impact of environmental regulations on the adoption of CATT remains to be elucidated.

A review of existing literature reveals that few studies have directly examined the impact of information literacy and environmental regulations on farmers' adoption of CATT. Given this, this paper explores the direct impact of both on farmers' adoption of CATT. The marginal contributions of this study are primarily reflected in the following three aspects: First, it constructs a theoretical analytical framework for the impact of information literacy indicators on farmers' adoption of CATT, enriching research on the effects of information literacy; Second, it provides a new research perspective for analyzing the adoption of CATT from the angle of environmental regulations; Third, it empirically analyzes the impact of information literacy and environmental regulations on farmers' adoption of CATT, enriching the study of factors influencing the adoption of CATT, and providing a new perspective for identifying the mechanisms linking information literacy, environmental regulations, and farmers' adoption of CATT.

Materials and methods

Method selection

Multivariate ordered Probit model

This paper primarily explores the impact of information literacy and environmental regulations on farmers' adoption of CATT. Farmers' adoption of CATT is a multi-category ordered variable. When analyzing such multivariate ordered discrete dependent variables, it is ideal to use an ordered Probit model or an ordered Logit model for result estimation. However, compared to the latter, the former imposes stricter assumptions. Therefore, drawing on the research methods of Fan et al. (2022) and Xiao et al. (2019), we assume that farmers' adoption of CATT satisfies the normal distribution condition and employ a multivariate ordered Probit model that is effective for ordered data for analysis. The specific econometric model equation is as follows:

$$Y_{1i} = \beta_{1i} X_i + \mu_{1i} \quad \text{(Eq.1)}$$

In the equation, Y_{1i} represents the farmer's willingness to adopt CATT, where $Y_{1i} = 1$ means that the farmer has adopted CATT, and $Y_{1i} = 0$ means that the farmer has not adopted CATT; X_i represents the explanatory variables influencing whether farmers adopt CATT. β is the estimated coefficient, and μ_{1i} is the random error term following a standard normal distribution. This model addresses the problem of predicting the probability of selecting one option over another. Whether to adopt the technology is a binary choice model suitable for the Probit model. Therefore, this paper uses this model for empirical analysis. The Probit empirical model is set up as follows:

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$$Y_i^* = \alpha + \beta_i X_i + \mu_i \quad \text{(Eq.2)}$$

$$Y_i = \begin{cases} 1, if > 0 \\ 0, if \leq 0 \end{cases} \quad \text{(Eq.3)}$$

where Y_i^* is the latent variable representing the adoption of CATT by the i-th farmer, Y_i is a binary variable ranging from 0 to 1. When the i-th farmer adopts CATT, $Y_i = 1$; when the i-th farmer does not adopt CATT, $Y_i = 0$. X is the core explanatory variable for land transfer, α is the constant term, β is the parameter to be estimated, and μ_{1i} is the random disturbance term.

Heckman two-stage model

In this study, farmers' technology adoption behavior is divided into two stages. The first stage involves whether farmers adopt the technology, and the second stage includes the degree of technology adoption. Since only farmers who adopted the technology in the first stage have data on the degree of adoption in the second stage, there may be a self-selection issue in the sample. To avoid potential selection bias issues, the Heckman two-stage model is employed for analysis (Liu et al., 2021; Ma and Gong, 2018). Additionally, the Heckman model addresses endogeneity issues through a two-stage selection process and the introduction of instrumental variables. The Heckman model estimation includes two methods: maximum likelihood estimation (MLE) and the two-step method. This chapter primarily uses the two-step method for model identification. First, a Probit model is used to establish the selection equation for farmers' adoption decisions regarding CATT, estimating the inverse Mills ratio (λ) for each farmer. This variable helps correct the sample selection bias. Second, the estimated inverse Mills ratio (λ) is used as an instrumental variable to correct selection bias and is included alongside other variables in the outcome equation for farmers' scientific adoption of CATT, thereby correcting the outcome equation in the second step.

Based on the estimated values obtained from *Equation 1*, the inverse Mills ratio for each farmer is calculated using the following formula:

$$\lambda_i = \frac{\varphi(\beta_{1i}, X_{1i})}{\phi(\beta_{1i}, X_{1i})} \quad \text{(Eq.4)}$$

Among them, λ_i represents the inverse Mills ratio of the i-th farmer, $\varphi(\beta_{1i}, X_{1i})$, $\phi(\beta_{1i}, X_{1i})$ are the density function and cumulative distribution function of the standard normal distribution, respectively.

In the second step, select a sample of farmers who have adopted CATT, introduce the inverse Mills ratio, and perform the following regression:

$$Y_{2i} = \alpha + \beta_{2i} X_{2i} + \gamma_{2i} \lambda_{2i} + \mu_{2i} \quad \text{(Eq.5)}$$

In the equation, Y_{2i}denotes whether the i-th farmer has scientifically adopted CATT; X_{2i} denotes the explanatory variables (including control variables) that influence the type of CATT adopted by farmer i; and the control variables in the second step are a subset of the control variables in the first step to ensure that the selection equation in the first step is identifiable; λi denotes the inverse Mills ratio for the i-th farmer; α is the constant term; β_{2i} and γ_{2i} are the coefficients to be estimated; μ_{2i} is the random error term, which follows

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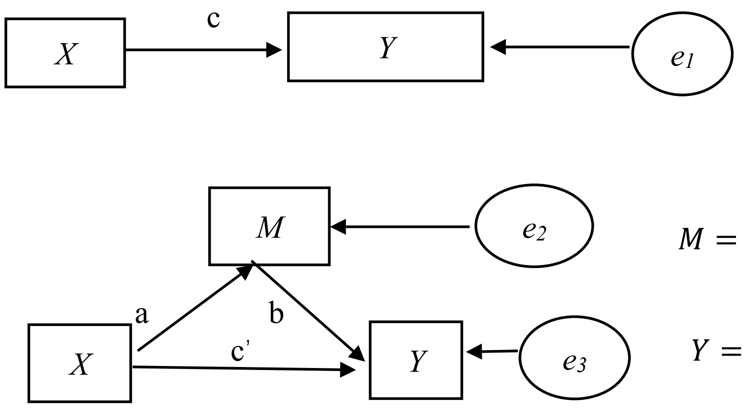
a normal distribution. The introduction of the inverse Mills ratio effectively overcomes sample selection bias, and the significance of its regression coefficients can be observed to test the validity of the Heckman model two-step method.

Mediator effect model

When considering the influence of independent variable X on dependent variable Y, if X influences Y through variable M, then M is referred to as a mediator (mediator or mediating variable). The effect of X on Y through the mediator M is referred to as the mediation effect. Therefore, in the causal path from the independent variable X to the dependent variable Y, the mediator occupies an intermediate position. It can also be said that the mediator transmits the effect of the independent variable on the dependent variable. Additionally, the mediating relationship implies a temporal sequence among the variables, such as X occurring before M, and M occurring before Y. The mediating variable selected in this study is information literacy, exploring whether environmental regulations influence farmers' adoption of conservation tillage technology by affecting information literacy. As introduced earlier, farmers' adoption behavior is a multivariate ordered dependent variable. Therefore, this paper employs hierarchical regression methods to test and analyze the mediation effect. The specific equation for the mediation effect testing model is as follows: The path of the mediation effect testing model is shown in *Figure 1*.



$$Y = cX + e_1 \quad (\text{Eq. } 6)$$

$$M = aX + e_2 \quad (\text{Eq. } 7)$$

$$Y = c'X + bM + e_3 \quad (\text{Eq. } 8)$$

Figure 1. *Path diagram of the mediation effect testing model*

The coefficient c in *Equation 6* represents the total effect of the independent variable X on the dependent variable Y.

The coefficient a in *Equation 7* represents the effect of the independent variable X on the mediating variable M.

The coefficient b in *Equation 8* represents the effect of the mediating variable M on the dependent variable Y after controlling for the influence of the independent variable X.

The coefficient c′ in *Equation 8* represents the direct effect of the independent variable X on the dependent variable Y after controlling for the influence of the mediating variable M. The product of coefficients a × b is the mediating effect, which is equal to the indirect effect.

Furthermore, the steps for testing the mediating effect are as follows: First, test whether the regression coefficient c of the independent variable X in *Equation 6* is significant. If the coefficient c is significant, continue to the next step of the test. If the

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coefficient c is not significant, stop the test, indicating that variable M does not produce a mediating effect. Step 2: Test whether the regression coefficients a and b of the independent variable X in *Equations 7* and *8* are significant. If both coefficients a and b are significant, continue to test whether coefficient c' is significant. If coefficient c' fails the significance test, it indicates that variable M has a complete mediating effect. If coefficient c' passes the significance test, it indicates that variable M has a partial mediating effect. Step 3: If at least one of the coefficients a and b is significant, continue with the Sobel test based on Step 2. If the Sobel test for variable M is not significant, it indicates that there is no mediating effect. Conversely, if it is significant, it indicates that a mediating effect exists, and the mediating effect ratio is the proportion of the mediating effect of independent variable X on dependent variable Y through variable M to the total effect of independent variable X on dependent variable Y, i.e., ab/c.

Sample sources and variable selection

Sample sources

(1) Sample selection areas

The geographical distribution of the survey sample was selected from multiple representative crop-growing regions within Shandong Province, specifically encompassing Dezhou and Liaocheng in the northwest; Heze and Linyi in the south; Weifang and Jinan in the central region; Qingdao and Yantai on the peninsula. This regional layout was chosen based on multiple considerations: firstly, Shandong ranks as China’s third-largest grain-producing province, holding significant importance within the nation’s agricultural sector. Its geographical position straddling the north-south divide of China endows it with marked variations in natural ecosystems and socio-economic conditions. The selected survey areas represent core crop-growing prefecture-level cities within Shandong Province, collectively accounting for 67.9% of the province’s total crop cultivation area in 2023. Consequently, these regions possess high representativeness and typicality in reflecting Shandong’s crop production status.

(2) Sample selection period

The sample selection period for this study is: February–July 2025.

(3) Respondent selection method

This study employs multistage stratified random sampling techniques, utilizing pre-obtained farmer lists. Respondents are farmers engaged in field crop cultivation (e.g., wheat, corn, vegetables, or oilseeds). The specific sampling process is as follows:

Stage 1: Stratification by prefecture-level city

The Shandong region is divided into northwest Shandong, Central Shandong, South Shandong, and the Shandong Peninsula. Within each region, the two cities with the largest cultivated areas for each crop are selected as representative agricultural production zones.

Stage 2: County and village selection

Within each selected city, 2–3 counties (or urban districts) were purposefully selected based on two criteria:

Each county randomly selected 2–3 representative villages from the local government’s registered agricultural village list, ensuring proportional coverage of townships and rural populations.

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Phase 3: Farmer selection

Using simple random sampling with a random number generator, farmers were selected from the final list of eligible households in each selected village.

(4) Respondent distribution

Based on total of sown area farm crops figures provided by the Shandong Statistical Yearbook, the sample size for each city was determined proportionally to its total of sown area farm crops, the respondent distribution as *Table 1*.

Table 1. *Number of respondents*

Region	City	Total of sown area farm crops (hectare)	Ratio
Northwest Shandong	Dezhou	1195461	16.00%
	Liaocheng	992666	13.29%
Southern Shandong	Heze	1567955	20.99%
	Linyi	996500	13.34%
Central Shandong	Weifang	978884	13.10%
	Jinan	626517	8.39%
Peninsula	Yantai	447413	5.99%
	Qingdao	665585	8.91%
	Total	7470981	1

Data source: Shandong Provincial Bureau of Statistics (2024); Shandong Statistical Yearbook (2024); http://tjj.shandong.gov.cn/tjnj/nj2024/zk/indexch.htm

Variable selection

Dependent variable

Farmers' Adoption of Conservation Tillage Practices. The dependent variable in this study is the degree of farmers' adoption of conservation tillage practices, based on the principles of conservation agriculture practices established by the Food and Agriculture Organization of the United Nations (FAO): (i) minimum soil disturbance, (ii) permanent soil cover, and (iii) biodiversity. A questionnaire on conservation tillage practices was designed, focusing on no-till/reduced-till, deep plowing, straw incorporation, crop rotation, and pest/disease management. Farmers adopting any single practice were coded as "1" (very low adoption); adopting any two practices as "2" (relatively low adoption); adopting any three practices is rated "3" for moderate adoption; adopting any four practices is rated "4" for relatively high adoption; and adopting all five conservation tillage practices is rated "5" for very high adoption, the questionnaire design as *Table 2*.

Core explanatory variables

Information literacy (IL). This study references the farmer information literacy framework constructed by Tian et al. (2023), Cui and Yu (2024), and Du et al. (2025), combined with the characteristics of relatively low information literacy levels among rural residents in China. It is developed across five dimensions: information awareness, information needs, information acquisition, and information application. Items were selected from the survey questionnaire for measurement to construct a information literacy evaluation index system.

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The entropy method was then applied to assess farmers' information literacy. Since the observed indicators share a unified dimension and are all positive indicators, the entropy method was directly employed to calculate weights, as detailed in *Table 3*.

Environmental regulations. Environmental regulations can be divided into three categories: incentive-based, restrictive, and guiding. Referring to previous scholars' research (Li et al., 2019; Xia et al., 2019; Meng et al., 2025), the indicator system is constructed as shown in *Table 4*. Since different environmental regulations have different effects, this paper will conduct separate regression analyses for different types. Construct an environmental regulation evaluation index system and apply the entropy method to measure environmental regulations. Since the observed indicators share consistent units and are all positive indicators, the entropy method is directly employed to calculate weights, as detailed in *Table 4*.

Table 2. *Measurement indicator*

No	Measurement indicator					
1	I prepare my fields using no-till or strip-till rather than deep plowing	1	2	3	4	5
2	When seeding, I use no-/low-tillage planters and disturb the soil as little as possible	1	2	3	4	5
3	During the growing season, I avoid additional deep 4tillage or plowing operations	1	2	3	4	5
4	After harvest, I leave crop residues on the soil surface to protect the ground	1	2	3	4	5
5	During fallow periods, I sow cover crops to maintain year-round soil cover	1	2	3	4	5
6	I never burn or remove straw; instead, I allow it to decompose in the field	1	2	3	4	5
7	I implement planned crop rotations to avoid continuous monoculture	1	2	3	4	5
8	I intercrop (or relay-crop) two or more species in the same field to enhance diversity	1	2	3	4	5
9	I adjust crop mixes seasonally to spread pest pressure and market risk	1	2	3	4	5
10	I employ highly effective, low-toxicity, low-residue chemical agents to control the occurrence of pests and diseases	1	2	3	4	5

Control variables

Drawing on existing research, this paper selects awareness of conservation tillage, farmland characteristics, agricultural subsidies, years of farming, and household characteristics as control variables.

Age: The age at which individuals engage in agricultural labor.

Awareness of conservation tillage: Awareness of conservation tillage.

Farmers' understanding of conservation tillage is one of the key factors in their adoption of this technology. The level of farmers' understanding mainly depends on whether they have received relevant training, which is closely related to whether the villages and towns where farmers live provide conservation tillage technical services. After learning about conservation tillage technology, farmers are more likely to adopt it.

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This paper uses whether farmers have received conservation tillage technical services as an indicator of their level of understanding.

Farmland characteristics: Farmland characteristics primarily include cultivated area, land fragmentation, whether the farmland is sloped, crop types, and soil fertility measures adopted. Larger cultivated areas and flatter land are more conducive to the use of agricultural machinery. More concentrated farmland is more conducive to large-scale production. This paper primarily uses whether farmland is concentrated to analyze its impact on conservation tillage behavior.

Agricultural subsidies: Government subsidies for agricultural activities.

Years of farming: Number of years agricultural laborers have engaged in farming.

Level of Education: Measured by the number of years the household head received full-time formal education.

Household characteristics: The number of agricultural laborers in the household.

Results

Regression results analysis

Using Stata 16.0, a Heckman selection model was applied to analyze farmers' adoption of CATT. The estimation results are shown in *Table 5*. It can be seen that λ is not zero and passes the significance test at the 10% level. This indicates that the model exhibits sample selection bias, and it is reasonable to use this model to analyze the sample data.

Table 3. *Information literacy indicator system*

Variable name	Items	Weight
Information awareness	Information is important for me	0.077
	Information can change my life	0.072
	Information can increase my income level	0.033
	The mutual exchange of information can boost local agricultural production	0.022
	Information can reduce the cost of technology use	0.058
Information needs	I am eager to get useful information on CATT	0.069
	I often need to use the Internet to search for information about CATT	0.078
	I often write it down When I come across information on CATT	0.061
	I'm willing to pay to get information on CATT as long as it's reasonably priced	0.069
Information acquisition	I can access information on CA via the internet	0.059
	I can access CATT information through paper-based printed materials such as books, newspapers and magazines	0.068
	I can always get more accurate information on CATT through various channels	0.058
	I can find a good source of counseling When I encounter difficulties in the agricultural production	0.093
Information application	After acquiring certain CATT, I will apply these techniques to actual planting	0.057
	I can use the information I obtain to solve practical agricultural production problems	0.025
	I was able to sort out their main meaning from a large amount of information on CATT	0.068
	I will adjust my production behavior in a timely manner based on the information I obtain	0.033

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Table 4. *Environmental regulation indicator system*

Variable name	Items	Weight
Incentive-based environmental regulation (IER)	The government provide green price subsidies	0.131
	The government offer higher rewards to farmers who implement CATT	0.101
	The Government provide water, electricity support who implement CATT	0.089
Constraint-based environmental regulation (CRE)	Relevant departments to monitor Arable land protection behavior	0.132
	The government impose severe penalties for soil damaging tillage practices	0.099
	The government have strict policies for agricultural production activities	0.126
Guidance-based environmental regulation (GER)	Frequent communication between agricultural farmers and technicians	0.089
	The Government promote and report on CATT	0.097
	The government provide training on CATT	0.136

Table 5. *Regression results*

Variable	Model (1)	Model (2)	Model (3)	Model (4)
Environmental regulations	0.255***			
Incentive-based environmental regulations (IER)		0.247***		
Constraint-based environmental regulation (CER)			0.362***	
Guidance-based environmental regulations (GER)				0.045
Information literacy (IL)	0.312***	0.188***	0.244***	0.412***
Age	-0.091**	-0.133***	-0.217***	-0.188***
Knowledge of conservation tillage	0.118**	0.168***	0.073***	0.199***
Arable land characteristics	0.008*	0.076***	0.099***	0.125**
Agricultural subsidies	0.117*	0.156***	0.238**	0.189*
Years of farming	0.225***	0.347***	0.255***	0.173***
Level of education	0.125***	0.233***	0.186***	0.277***
Household characteristics	-0.325***	-0.244***	-0.353***	-0.221***
Inverse mills ratio	-1.242***	-1.563***	-1.335***	-1.721***
Pseudo R^2	0.4532	0.3763	0.3865	0.4118

*, **, *** means $p < 0.1$, $p < 0.05$ and $p < 0.01$

(1) Analysis of the impact of core variables

Incentive regulations have a significant promotional effect on farmers' adoption of CATT, indicating that such regulations exert a positive and significant influence on adoption. Through policy incentives and other measures, incentive regulation policies enhance farmers' awareness of the importance of environmental protection, prompting them to prioritize sustainable development in their production processes and thereby adopt CATT. Incentive regulation policies often provide economic incentives to farmers engaged in green production, such as subsidies or preferential policies, thereby stimulating farmers' enthusiasm for participating in conservation tillage and achieving an organic integration of economic benefits and environmental goals. Incentive regulation policies encourage agricultural technological innovation, providing farmers with technical training in conservation tillage to help them reduce environmental pollution during production. Incentive-based regulatory policies reward farmers who meet green production standards, guiding them to transform their production methods and adopt

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environmental protection measures. In summary, incentive-based regulatory policies significantly and positively influence farmers' adoption of conservation tillage through multiple channels, prompting them to prioritize environmental protection in agricultural production, thereby contributing to the achievement of sustainable development goals and ecological civilization construction.

The regression coefficients for constraint-based environmental regulations on farmers' adoption of CATT are 0.247, passing the 1% significance level test. This indicates that they have a positive promotional effect on farmers' adoption of CATT. Possible reasons include: first, CATT enable farmers to achieve plowing, loosening, mixing, and breaking up of soil, and reasonable deep plowing can significantly increase yields, thereby reducing the use of chemical fertilizers. Local government supervision of fertilizer and pesticide application in agricultural production can encourage farmers to adopt CATT. Additionally, crop regulation imposes mandatory constraints on farmers' actual production behaviors, increasing the cost of non-compliance. After weighing the costs of non-compliance, economic rationality will encourage farmers to transition toward green production (Tan et al., 2021).

Guidance-oriented environmental regulations have a negligible impact on farmers' adoption of CATT. Possible reasons include: the implementation of conservation tillage requires sustained farmer investment, while technical demonstrations provide farmers with technical information but fail to sustainably reduce the costs of implementing conservation tillage, leading to low perceptions of the technique's effectiveness among farmers (Wang, 2021). Therefore, in terms of directly promoting farmers' adoption of CATT, technology demonstrations have not yet fully fulfilled their intended role.

Information literacy has a positive impact on farmers' adoption of CATT, and this effect is statistically significant at the 5% level, indicating that the higher farmers' information literacy, the more willing they are to adopt CATT. Conservation tillage is a systematic engineering project and an integrated technological system that requires matching human capital to play a synergistic and supportive role. Information literacy serves as an important indicator and component for measuring human capital levels in modern information societies, reflecting farmers' ability to process and apply information in agricultural production and their capacity to identify high-quality information during searches. The higher the information literacy of farmers, the richer their information knowledge, and the stronger their ability to obtain, process, apply, and share information. With the continuous improvement of internet infrastructure and the increasing efforts of the state in rural informatization and digitalization, the information divide between urban and rural areas is gradually narrowing, and a large amount of information resources are gradually being disseminated to rural areas. When faced with a vast amount of information resources, farmers with high information literacy can effectively identify and select information related to CATT, obtain more accurate and reliable information knowledge, master the key points and methods of technical operation, and thus adopt CATT according to certain standards. This helps change traditional production concepts, promotes the adoption of CATT, and plays a positive role in leveraging the application benefits of the technology.

(2) Analysis of the impact of control variables

There is a significant negative correlation between the age of sample farmers and their adoption of CATT, meaning that as farmers age, their likelihood of adopting new technologies decreases, and the extent of adoption is also negatively affected by age. This

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result can be interpreted from multiple perspectives: first, younger farmers typically possess stronger learning abilities and adaptability, making them more receptive to new technologies and ideas. In contrast, older farmers may adopt a more cautious attitude toward new technologies due to historical experience, traditional beliefs, and limitations in learning ability and energy. Second, younger farmers typically exhibit stronger adventurous spirit and innovative awareness, are more inclined to try new technical methods, and are willing to take on certain risks; older farmers, however, tend to hold more conservative views and adopt a more cautious attitude toward the potential risks and uncertainties associated with new technologies. Additionally, as times change and technology advances, CATT are constantly being updated and upgraded. Younger farmers, who have easier access to and understanding of these new technologies, are better able to keep pace with technological changes; older farmers, however, may lag behind in adopting new technologies due to limited information channels or insufficient understanding of these technologies.

Soil characteristics play a foundational role in decision-making regarding the application of CATT. Analysis indicates that the current degree of farmland concentration is significantly positive, as more concentrated farmland areas facilitate mechanized operations and are more conducive to the application of CATT.

The regression coefficient for whether farmers have received CATT services is significantly positive, indicating that such services have a positive influence on farmers' adoption of CATT. Farmers generally have lower educational levels, making it difficult for them to master new technologies, leading to reluctance to adopt them. Only through one-to-many technical guidance from agricultural extension workers and training in CATT for farmers, along with technical demonstrations and guidance on conservation tillage, will farmers have the ability and confidence to adopt CATT.

The impact of agricultural subsidies on farmers' adoption of CATT is significantly positive at the 1% level, indicating that farmers who have received agricultural subsidies are more likely to adopt CATT. In terms of agricultural subsidies, subsidy policies can effectively alleviate the cost burden farmers bear when implementing conservation tillage production, stimulating farmers' enthusiasm for participating in conservation tillage. Therefore, farmers, considering economic rationality, are more inclined to adopt CATT to obtain the direct economic benefits brought by subsidies.

The impact of years of farming on farmers' adoption of CATT. The regression coefficient value is significantly positive. Years of farming has a significant impact on farmers' accumulation of experience and skills. As years of farming increases, farmers can accumulate more experience and skills, master more planting techniques and methods, and better address various issues during the production process. This may help improve farmers' conservation tillage levels. An increase in years of farming may also lead to changes in farmers' mindset. Younger farmers may be more inclined to pursue yield and profit, while older farmers may place greater emphasis on traditional farming methods. Therefore, older farmers may be more proactive in conservation tillage. An increase in years of farming may lead farmers to adopt different approaches to resource utilization and management. New farmers may be more inclined to use more fertilizers and pesticides to achieve higher yields. Experienced farmers, on the other hand, may place greater emphasis on land protection and resource conservation, adopting more protective farming practices.

From the perspective of the impact of household characteristics on farmers' adoption of CATT, the number of agricultural laborers has a negative impact on farmers' adoption

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of CATT. The possible reason is that the adoption of CATT incurs certain costs. To reduce production inputs, households with more agricultural laborers may reduce the use of mechanized technologies. Therefore, households with more agricultural laborers are less inclined to adopt CATT.

Mediation analysis

To further explore the mechanism through which environmental regulations influence farmers' adoption of conservation agriculture practices, this study employed the stepwise regression method within the mediation analysis framework (*Table 6*). As shown in the regression results of Column (1), incentive-based environmental regulations significantly influence the adoption of conservation agriculture practices. When incentive-based environmental regulations and information literacy are included in the same regression model, the regression results in column (2) indicate that incentive-based environmental regulations still have a significant positive impact on farmers' adoption of conservation agriculture practices, suggesting that incentive-based environmental regulations not only directly influence farmers' adoption of conservation agriculture practices but also exert an indirect influence through information literacy. The regression results in columns (3) and (4) indicate that restrictive environmental regulations do not significantly influence farmers' information literacy, suggesting that restrictive environmental regulations do not mediate farmers' adoption of conservation agriculture practices. The regression results in columns (5) and (6) indicate that guiding environmental regulations have a significant positive impact on farmers' information literacy. When both guiding environmental regulations and information literacy are included in the same model, guiding environmental regulations still have a significant positive impact on farmers' adoption of protective agricultural practices, indicating that guiding environmental regulations not only directly influence farmers' adoption of protective agricultural practices but also exert an indirect influence through information literacy.

Table 6. *Mediation effect results*

	IL (1)	CATT (2)	IL (3)	CATT (4)	IL (5)	CATT (6)
IER	0.087***	0.275***				
CER			-0.035	-0.044*		
GER					0.056***	0.133**
Control variables	Control	Control	Control	Control	Control	Control
Mediation effect coefficient	0.0277***				0.0075***	
Direct effect coefficient	0.246***				0.132***	

*, **, *** means $p < 0.1$, $p < 0.05$ and $p < 0.01$

Conclusions and recommendations

Conclusion

This study takes Shandong Province as its research context, combining theoretical research, current status analysis, field surveys, and modeling analysis to thoroughly examine the factors influencing farmers' adoption of CATT. The Heckman two-stage model was applied to analyze the significant constraints and their underlying relationships, determining the specific impact effects of each factor. Correspondingly,

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policy recommendations were proposed for the promotion of CATT in Shandong Province. The main research conclusions are as follows:

Environmental regulations, as an important factor influencing farmers' production behavior, can positively promote the adoption of CATT by farmers. Specifically, incentive regulations and constraint regulations both have a significant positive impact on farmers' adoption of CATT. Additionally, both incentive regulations and constraint regulations exert a certain positive moderating effect. However, guiding environmental regulations do not significantly influence farmers' adoption of CATT, possibly because technology demonstrations have not yet fully realized their intended effects.

Information literacy has a positive impact on farmers' adoption of CATT. Farmers with high information literacy can effectively identify and select information related to CATT, obtain more accurate and reliable information and knowledge, master the key points and usage methods of the technology, and thus adopt CATT according to certain standards. This helps change traditional production concepts, thereby promoting the adoption of CATT and playing a positive role in realizing the application benefits of the technology.

From the perspective of control variables, there is a significant negative correlation between the age of sample farmers and their adoption of CATT, meaning that as age increases, farmers' likelihood of adopting new technologies decreases, and the extent of adoption is also negatively influenced by age. The more concentrated the farmland area, the more conducive it is to mechanized operations, and the more conducive it is to the adoption of CATT. CATT services have a positive impact on farmers' adoption of CATT. Agricultural subsidy policies can effectively alleviate the cost burden farmers bear in implementing conservation tillage production, thereby stimulating farmers' enthusiasm for adopting new technologies. Younger farmers may be more inclined to pursue yield and profit, while older farmers place greater emphasis on traditional farming methods. Households with more agricultural laborers are less inclined to adopt CATT.

Incentive-based environmental regulations and guidance-based environmental regulations can not only directly influence farmers' adoption of conservation agriculture practices, but also exert an indirect influence through information literacy. Constraint-based environmental regulations do not have a significant impact on farmers' information literacy, indicating that constraint-based environmental regulations do not play a mediating role in farmers' adoption of conservation agriculture practices.

Recommendations

Strengthen information infrastructure construction in rural areas to lower the "threshold" for farmers to access information. On one hand, update and improve existing rural information infrastructure, dispatch professional technical personnel to form maintenance teams, and implement regular inspection systems to ensure the efficiency and accuracy of farmers' access to information resources. On the other hand, leverage the information rural development trend to accelerate the introduction and construction of mobile internet and information service platforms. Fully utilize the advantages of modern information technologies such as the internet, artificial intelligence, and 5G communication—including their fast transmission speeds, diverse methods, and rich content—to enhance information transmission efficiency, gradually address the information asymmetry challenges faced by farmers in agricultural production, and reduce the costs of information search and acquisition.

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Increase fiscal subsidies and credit support to specifically cover the purchase costs of conservation tillage machinery and potential losses during the technology transition period. Simultaneously, establish a multi-tiered technology extension and socialized service system. By creating demonstration fields and cultivating specialized service organizations, provide farmers with practical technical guidance and solutions tailored to their production realities. Furthermore, explore ecological compensation mechanisms that internalize environmental benefits into farmer income, synergizing with agricultural insurance and land transfer policies. Through these systemic measures, we aim to position conservation agriculture as an economically viable, technically accessible, and long-term beneficial choice for farmers. This approach ultimately achieves a win-win scenario of sustainable farmland use, increased farmer income, and enhanced national ecological security.

Implement differentiated strategies to enhance information literacy. On one hand, focus on large-scale, low-income, and new-generation farmers as key training targets to strengthen their information awareness, improve their ability to learn information knowledge, and enhance their capacity to obtain, process, and utilize information, thereby playing a leading and driving role. On the other hand, address the prominent issues in information literacy among small-scale, high-income, and older-generation farmers by promptly formulating precise and differentiated countermeasures to enhance their information literacy levels and promote coordinated development among farmers.

Enhance technical publicity efforts to improve farmers' technical understanding. Farmers' understanding of technology directly influences their willingness to adopt it and their decision-making. Therefore, strengthening the publicity and promotion of CATT is crucial. First, design catchy slogans and utilize village broadcasts and television advertisements for publicity. These methods are intuitive and vivid, capable of attracting farmers' attention and rapidly increasing awareness of CATT. Second, emphasizing the economic benefits of CATT is also very important. As rational economic entities, farmers are more inclined to adopt technologies that increase economic returns. Therefore, during the promotion process, we should highlight the advantages of CATT in improving land productivity, reducing labor input, and increasing crop yields, allowing farmers to see tangible benefits. Additionally, training agricultural extension personnel is crucial. Agricultural extension workers serve as a bridge between farmers and technology, and their professional competence and promotional capabilities directly impact the effectiveness of technology promotion. Therefore, efforts should be made to strengthen the theoretical knowledge of agricultural extension workers, enhance their professional capabilities, and improve their promotional skills. Finally, establishing demonstration sites is also an effective method for promoting CATT. Through the construction of demonstration sites, farmers can witness the actual application effects of the technology firsthand, thereby strengthening their resolve to adopt it.

Accelerate the establishment of a farmer information literacy education system and enhance farmers' information literacy levels Research has found that improving information literacy can promote farmers' adoption of conservation tillage production technologies. While strengthening information infrastructure construction, efforts should also be made to enhance their information literacy levels. On one hand, strengthen publicity and education through organizing training programs, conducting distance education, and promoting information applications to help farmers master the use of information tools such as the internet and smartphones, enabling them to understand the practical value of smartphones in daily life and improve their ability to obtain, analyze,

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and utilize information; On the other hand, improve farmers' information problem-solving literacy by promoting and training specialized information skills applications such as rural e-commerce and smart agricultural management devices, encouraging farmers to apply the information skills they have learned to agricultural production and operations, such as selling agricultural products through e-commerce platforms and optimizing production management using smart agricultural management devices.

Implement differentiated environmental regulation strategies. Given the diversity of operational objectives resulting from differences in farmers' ages and production scales, which influence their perception and response to environmental policies, to enhance the adoption effectiveness of conservation tillage production technologies, policies should be designed and implemented based on farmers' information reception preferences, precisely matching needs with policies to comprehensively promote farmers' active adoption of conservation tillage production technologies.

Improve rural environmental regulations. Strengthen the constraining and incentivizing roles of environmental regulations while enhancing their guiding role. In promoting the resource utilization of crop farming, increase the severity of penalties for pollution, expand the scale of subsidies for conservation tillage to offset its costs; simultaneously, enhance farmers' conservation tillage skills through engaging and accessible training programs, ensuring they truly master these skills, and strengthen publicity and education on the value of environmental protection to guide farmers in scientifically understanding the value of conservation tillage. Establish and implement a reasonable penalty mechanism to constrain farmers' behaviors that violate protective farming production regulations. Effective regulatory environmental controls are also necessary to prevent further environmental degradation. Appropriate and reasonable penalty mechanisms can serve as a constant reminder to farmers to participate in conservation tillage production. Therefore, during the promotion of conservation tillage, government departments should establish and implement reasonable penalty mechanisms, establish grassroots organizations led by village-level administrative supervision, and strictly monitor behaviors that do not comply with conservation tillage production regulations.

REFERENCES

[1] Avemegah, E., May, C. K., Ulrich-Schad, J. D., Kovács, P., Clark, J. D. (2024): Understanding farmers' adoption of conservation tillage in South Dakota: a modified application of the theory of planned behavior. – Journal of Soil & Water Conservation 79(1): 31-42.

[2] Brozovic, B., Jug, I., Durdevic, I. J. D. (2023): Initial weed and maize response to conservation tillage and liming in different agroecological conditions. – Agronomy 13(4): 1116.

[3] Chengot, R., Zylberman, R., Momblanch, A. (2024): Evaluating the impacts of agricultural development and climate change on the water-energy nexus in Santa Elena (Ecuador). – Environmental Science & Policy 152: 103656.

[4] Cui, Z. D., Yu, Z. G. (2024): Study on the impact of information literacy on farmers' adoption of conservation tillage techniques: with a discussion on the moderating effect of ecological compensation. – Journal of Chinese Ecological Agriculture 33(3): 590-604.

[5] Deng, Y. Y., Zhu, J. F. (2023): Yield increase and stability effects of adopting conservation tillage technology. – Resources Science 45(10): 2050-2063.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2306_1176911790

[6] Du, Y., Feng, H., Zhang, Q., Zheng, S. (2025): Influence of information literacy on farmers' green production technology adoption behavior: the moderating role of risk attitude. – Agriculture 15(7): 701.
[7] Fan, J. X., Yu, Z. G., Cui, Z. D. (2022): The impact of perceived agency and contextual constraints on farmers' adoption of conservation tillage technologies. – Research on Agricultural Modernization 43(6): 1042-1053.
[8] Griliches, Z. (1957): Hybrid corn: an exploration in the economics of technological change. – Econometrica 25(4): 501-522.
[9] He, J., Li, H., Gao, H. (2006): Subsoiling effect and economic benefit under conservation tillage mode in Northern China. – Transactions of the Chinese Society of Agricultural Engineering 22(10): 62-67.
[10] Hu, R. F., Wang, R., Sun, Y. D. (2019): Agricultural socialized technical services and farmers' sources of technical information: a survey of 2,293 farmers in seven provinces. – Research on Science and Technology Management 39(22): 99-105.
[11] Huang, Z., Zhuang, J., Xiao, S. (2022): Impact of mobile internet application on farmers' adoption and development of green technology. – Sustainability 14(24): 16745.
[12] Jiang, W. J., Yan, T. W., Zhang, J. B. (2021): can internet use promote farmers' voluntary adoption of straw returning technology? An empirical analysis based on the endogenous conversion probit mode. – Agricultural Technology Economics 3: 50-62.
[13] Kang, H. (2022): Overview of the development of conservation tillage and its impact on soil in the Hexi irrigation district. – Water Conservancy Technology Supervision 8(2023): 179-182.
[14] Li, F. N., Zhang, J. B., He, K. (2019): The influence of informal institutions and environmental regulations on farmers' green production behavior: evidence from a survey of 1,105 households in Hubei Province. – Resources Science 41(7): 1227-1239.
[15] Li, T. L., Jiang, C. Y. (2022): The influence mechanism of information literacy on high-quality farmers' participation in rural digital governance: empirical evidence from 1280 high-quality farmers in Northwest China. – E-Government 6: 86−98.
[16] Ling, M. A., Zhou, G., Zhang, J. (2025): Long-term conservation tillage changes the diversity, assembly and network stability of soil diazotrophic community. – Pedosphere 35(2): 299-311.
[17] Liu, H. B., Wu, M. Y., Ma, X. L. (2021): A study on farmers' adoption behavior of conservation tillage technology and its influencing factors based on distributed cognition theory. – Chinese Journal of Land Science 35(10): 75-84.
[18] Luo, L., Mo, D. S. (2025): the impact of farmers' digital literacy on the adoption of conservation tillage behavior: an analysis based on CLES data. – Chinese Journal of Agricultural Machinery and Chemistry 46(8): 305-315.
[19] Ma, C., Gong, Z. W. (2018): Analysis of fruit farmers' adoption behavior of conservation tillage technology based on a two-stage choice model: a case study of Lixian County, Shaanxi Province. – Journal of Agricultural and Forestry Economics and Management 3: 302-308.
[20] Ma, N., Zhang, X. Y., Liu, Q. X. (2025): The impact of information literacy on farmers' participation in e-commerce: the mediating role of perceived benefits and perceived risks and the moderating role of government support. – Journal of Agricultural Library and Information Science 37(2): 88-99.
[21] Marquardt, T., Hatfield, J. L., Parkin, T. B., Prueger, J. H. (2019): Conservation tillage impacts on soil, crop, and the environment. – Sustainability 11(8): 2245.
[22] Meng, N., Zhou, J., Zhang, S. M. (2025): The impact of environmental regulations on farmers' adoption of conservation tillage technologies: a study based on 685 farm household survey data from the Black Soil Region of Liaoning Province. – Ecological Economy 5(2023): 118-126.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2306_1176911790

[23] Mirsky, S. B., Ryan, M. R., Curran, W. S. (2012): Conservation tillage issues: cover crop-based organic rotational no-till grain production in the mid-Atlantic region, USA. – Renewable Agriculture & Food Systems 27(1): 31-40.
[24] Nugroho, P. A., Juhos, K., Pretti, N., et al. (2023): Long-term conservation tillage results in a more balanced soil microbiological activity and higher nutrient supply capacity. – International Soil and Water Conservation Research 11(3): 528-537.
[25] Olorunfemicc, O. D. (2024): The adoption of sustainable farming practices by smallholder crop farmers: micro-level evidence from north-eastern South Africa. – Agriculture 14: 2370.
[26] Pei, X. H., Shen, Y. J., Zhao, M. J. (2025): The impact of family life cycle on farmers' adoption of conservation tillage technology: an empirical test from main grain farmers in Heilongjiang, Henan, and Hunan Provinces. – Arid Zone Resources and Environment 7: 25-38.
[27] Peng, X. H., Yan, X. H. (2022): The impact of internet use on the adoption of green production technologies by apple growers. – Northern Horticulture 17: 147-153.
[28] Qian, D., Wei, X. J., Zhu, G. Q. (2024): A study on farmers' ecological farming behavior based on the CLT-VBN Integrated Framework. – Journal of China Agricultural University 29(8): 251-268.
[29] Ren, Z., Guo, Y. (2023): The impact of environmental regulations and social capital on farmers' adoption of low-carbon agricultural technologies. – Journal of Natural Resources 38(11): 287-296.
[30] Schipanski, M. E., Barbercheck, M., Drinkwater, L. E. (2014): Croprotations, soil health, and plant–microbe interactions. – Agronomy 125: 249-307.
[31] Shen, Y. (2025): Current status and reflections on the informatization monitoring of conservation tillage in Jilin Province. – Agricultural Engineering Technology 45(5): 88-90.
[32] Shen, Y. J., Gu, M. C., Tian, P. P. (2025): The impact of environmental regulations and green awareness on farmers' adoption of green production technologies: a discussion on the moderating role of social capital. – Arid Zone Resources and Environment 39(1): 1-15.
[33] Shi, Z. H., Fu, Y. (2022): Influence mechanism of social network on farmers' behavior of purchasing socialized service. – Journal of Arid Land Resources and Environment 36(12) (2023): 7−14.
[34] Subrahmaniyan, K., Parthipan, T., Rajavel, M. (2024): Impact of conservation tillage practices in rice-blackgram cropping system. – Bangladesh Journal of Botany 53(3): 519-525.
[35] Tan, Y. F., Zhang, S. X., Lu, Q. (2021): Environmental regulations, technology selection, and green production transformation of livestock farmers: an empirical analysis based on an endogenous conversion regression model. – Arid Zone Resources and Environment 10: 69-76.
[36] Tellez-Riocc, A., Garcia-Marco, S., Navas, M. (2015): N2O and CH4 emissions from a fallow-wheat rotation with low N input in conservation and conventional tillage under a Mediterranean agroecosystem. – Science of the Total Environment 508: 85-94.
[37] Tian, X., Sun, R. Y., Li, Z. (2023): Effects of information literacy on farmers' transition to green production. – Applied Ecology and Environmental Research 21(4): 3445-3463.
[38] Tong, S. Y., Sun, C. Z. Q., Chen, S. (2022): Four main models of conservation tillage and supporting technologies in Heilongjiang Province. – Agricultural Machinery Technology Promotion 10(2023): 38-39.
[39] Wang, X. B., Cai, D. X., Hoogmoed, W. B. (2007): Developments in conservation tillage in rainfed regions of North China. – Soil & Tillage Research 93(2): 239-250.
[40] Wang, X. C., Qi, Z. H., Yang, C. Y. (2021): The impact of social networks on farmers' ecological production behaviors: a comparative analysis of different ecological production behaviors. – Hubei Agricultural Sciences 60(17): 161-167.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2306_1176911790

[41] Xia, J. Q., He, K., Zhang, J. B. (2019): The impact of environmental regulations and village rules on farmers' green production intentions: a case study of waste resource utilization in large-scale pig farming. – Chinese Journal of Ecological Agriculture (Chinese and English) 27(12): 1925-1936.

[42] Xiao, S. S., Lang, H., Cao, M. Z. (2019): Farmers' willingness and funding models for compensation for the ecological service value of conservation tillage: a case study in Sichuan Province. – Journal of Northeast Agricultural University: Social Sciences Edition 17(6): 1-9.

[43] Xu, J. B., Wang, Y., Li, C. X. (2021): The impact of farmers' perceptions on their willingness to engage in green agricultural production under environmental regulation policies: evidence from data on 698 planting households in Heilongjiang Province. – Journal of China Agricultural University 2: 164-176.

[44] Yan, B. B., Liu, T. J. (2022): Information service, information literacy and farmers' adoption of green control technology. – Journal of Arid Land Resources and Environment 36(5) (2023): 46−52.

[45] Yan, F. X., Yan, T. W. (2020): Cognitive conflict and farmers' adoption of conservation tillage technology: an analysis of the moderating effect of farmers' information acquisition. – Research on Agricultural Modernization 41(2): 265-274.

[46] Yi, C., Xu, B., Lin, F. (2024): Nonlinear associations and threshold effects between agricultural industrial development and carbon emissions: insights from China. – Environmental Research Communications 6(10): 105038.

[47] Yu, H., Sun, Y., Cui, Y. (2025): The impact of farmers' cognition and attitudes on the adoption of conservation tillage: an empirical study based on the Lishu Model. – Sustainability17(12): 1-12.

[48] Yuan, Y., Sun, L., She, Z. (2025): Influence of digital literacy on farmers' adoption behavior of low-carbon agricultural technology: chain intermediary role based on capital endowment and adoption willingness. – Sustainability 17(5): 2187.

[49] Zafar, S., Rasool, H., Tarique, M. (2023): Is agricultural development good for carbon mitigation in India? Evidence from the asymmetric NARDL model. – Management of Environmental Quality: An International Journal 34(1): 234-249.

[50] Zentner, R. P., Mcconkey, B. G., Campbell, C. (1996): Economics of conservation tillage in the semiarid prairie. – Canadian Journal of Plant Science 76(4): 697-705.

[51] Zhang, H. L., Li, J. Y., Shi, D. D. (2021): a study on the impact of environmental regulations and ecological awareness on farmers' adoption of organic fertilizers. – Chinese Journal of Agricultural Resources and Regional Planning 42(11): 42-50.

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