frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 30 September 2025
DOI 10.3389/fenvs.2025.1656461

OPEN ACCESS

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RECEIVED 30 June 2025
ACCEPTED 19 September 2025
PUBLISHED 30 September 2025

CITATION
Ma Y and Sun Z (2025) Government support, internal perceptions, and mountain farmers' conservation tillage adoption: evidence from Enshi City, Hubei Province.
Front. Environ. Sci. 13:1656461.
doi: 10.3389/fenvs.2025.1656461

Government support, internal perceptions, and mountain farmers' conservation tillage adoption: evidence from Enshi City, Hubei Province

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As a vital measure for promoting the green transformation of agriculture, the analysis of the impact of government support and farmers' internal perceptions (subjective norms, attitudes toward behaviour, behavioural intention) on the adoption of conservation tillage technology is essential for optimizing policy design and promoting sustainable agricultural development. Based on the Stimulus-Organism-Response (SOR) theoretical model, this study constructs a relational model involving government support, farmers' internal perceptions, and conservation tillage technology adoption behaviour. Most existing studies have examined internal or external factors in isolation, thus lacking an understanding of how government support influences farmers' adoption of conservation tillage through psycho-institutional interactions. This study addressed this gap by using the integrated SOR framework and Structural Equation Model. An empirical analysis was conducted using survey data from 245 farmers in Enshi City, Hubei Province. The effective questionnaire rate was 94.23%. The results show that both government support and farmers' internal perceptions significantly positively influence conservation tillage technology adoption behaviour. Furthermore, bootstrap analysis with 2000 replicates demonstrated that internal perceptions serve both as individual and chain mediators between government support and conservation tillage technology adoption behaviour. Therefore, in promoting conservation tillage technology, the role of government support should be effectively utilized. By strengthening farmers' internal perceptions, their awareness, familiarity, and satisfaction with conservation tillage technology can be increased, thus encouraging its adoption and dissemination. This will contribute to implementing the rural revitalization strategy and achieving the green transformation of agriculture.

KEYWORDS

conservation tillage technology, farmland protection, government support, internal perception, adoption behaviour, SOR theoretical model

10.3389/fenvs.2025.1656461

1 Introduction

United Nations Sustainable Development Goals (SDGs) clearly state that climate change and environmental degradation have become critical challenges to global sustainable development (Williamson et al., 2018). Agriculture, being a foundational and strategic industry, has its sustainability intrinsically tied to ecological-environmental quality. However, the process of agricultural modernization, characterized by the excessive use of chemical inputs, has led to a series of environmental and economic externalities, which include land degradation, aggravated non-point source pollution, and biodiversity loss (Kay et al., 2022). These issues pose systemic risks to the global food security system.

As the world's fourth most important staple crop, the potato offers significant agronomic advantages for global food security, exemplified by its high water-use efficiency, which requires only 50% of the irrigation water needed for wheat (Li et al., 2018). China, the world's top potato producer, maintains a stable cultivation area of approximately 4.67 million hectares, with annual production reaching around 90 million metric tons (Liu et al., 2021). In 2015, China formally integrated potatoes into its national staple food strategy, elevating them to a position alongside rice, wheat, and maize (Ni et al., 2024; Li and Song, 2022). However, the commercialization of potato farming has intensified reliance on agrochemicals, leading to diminishing marginal returns (Lun et al., 2024) and posing risks to product safety and ecological sustainability. In response, a multi-dimensional governance framework has been established, combining policy, technology extension, and market incentives (Xie and Huang, 2021; Lin et al., 2025). Notably, Conservation tillage technology has demonstrated potential to increase soil organic matter by 12%–15% and reduce non-point source pollution by approximately 30% (Tian et al., 2024). Despite these benefits and generally positive attitudes among farmers, the adoption rate of conservation tillage technology remains low, revealing a significant intention-behaviour gap. Furthermore, government subsidies play a critical role in shaping farmers' decisions. Thus, investigating the determinants affecting conservation tillage technology adoption is crucial to overcoming extension barriers and promoting sustainable agricultural transitions.

Conservation tillage technology, a cornerstone of sustainable agriculture, encompasses practices designed to balance resource conservation, environmental protection, and economic benefits through "reduced input, low pollution, and high efficiency" (Kassam et al., 2019). Research on its adoption is well-established, with influencing factors broadly categorized as endogenous and exogenous. Endogenous factors stem from farmers' internal psychological and cognitive mechanisms, often analyzed through frameworks like the Theory of Planned Behaviour (TPB) (Ajzen, 1991). Key determinants include Perceived Behavioural Control (Borges et al., 2014), Subjective Norms, Attitude toward Behaviour (Wan et al., 2017; Barrett and Dannenberg, 2014; Milfont et al., 2010), and Behavioural Intention (Liu et al., 2020; Yang et al., 2022; Bamberg et al., 2007; Bratt, 1999). These shape farmers' attitude toward behaviour, forming a critical pathway for green agricultural transition. Farmer characteristics are also significant: empirical studies indicate that age (Li et al., 2024; Yu et al., 2021), gender (with males showing higher adoption willingness) (Arcury and Christianson, 1990), and education level (positively correlated with adoption) are influential (Bravo-Monroy et al., 2016; Alibeli and Johnson, 2009). Exogenous factors primarily involve the institutional environment. Social capital mitigates adoption uncertainty via information sharing and trust (Tran et al., 2023). Government support play a guiding role through policy regulation, economic incentives, and extension services (Alt et al., 2024; Vis et al., 2023; Chen et al., 2022; Hruska, 1990; Braito et al., 2020; Jahrl et al., 2012; Whitaker, 2024). Furthermore, market incentives, such as premium pricing for quality products, enhance the economic attractiveness of conservation tillage technology adoption (Zhang et al., 2020b).

Although existing research offers a foundational understanding of conservation tillage adoption, several critical gaps and limitations remain, underscoring the necessity of the current study. (1) Theoretical fragmentation: most studies rely on isolated theoretical frameworks, such as the Theory of Planned Behaviour (TPB) or the Theory of Reasoned Action (TRA), with limited attempts to integrate multiple theories for a more holistic understanding of farmer decision-making—without integrating behavioural and institutional economic perspectives (Gao et al., 2020; Anibaldi et al., 2021). (2) Unidimensional focus: the scope of existing work is often constrained by a unilateral focus—either on psychological (endogenous) factors or institutional (exogenous) factors. Endogenous (psychological) and exogenous (institutional) determinants are typically examined in isolation, leaving the psycho-institutional interplay largely unexplored (Doan et al., 2025). (3)Methodological constraints: Conventional Probit/Logit models struggle to capture mediation among latent constructs, whereas the Structural Equation Model (SEM) has rarely been employed to simultaneously estimate the direct and indirect effects of policy incentives, social capital and psychological factors (Wang et al., 2019). Recent evidence further shows that conservation agriculture covers <1.25% of cultivated land in sub-Saharan Africa, largely due to information asymmetry, lack of locally-adapted machinery and credit constraints (Bilal and Jaghdani, 2024; Araya et al., 2024). Hence, to unravel the "cognitive-behavioural" paradox, the present study responds to these gaps by offering an integrated theoretical framework that simultaneously incorporates psychological and institutional variables, expanding the analytical scope to jointly model endogenous and exogenous drivers, and employing robust SEM to test endogenous drivers mediation effects on farmers' adoption behaviour.

This study focuses on Enshi City in Hubei Province as a case study. It utilizes the perspective of government-farmer interaction and employs the SOR theoretical model to develop a SEM model. This model systematically examines how external government support and internal farmer perceptions work together to influence the adoption of conservation tillage technology by farmers. The study aims to address three core questions: (1) Does government support significantly impact the technology adoption behaviour of farmers in mountainous areas? (2) How do farmers' internal perceptions—such as subjective norms, behavioural attitudes, and intentions—act as mediating factors between government support and their adoption of technology? (3) Can the

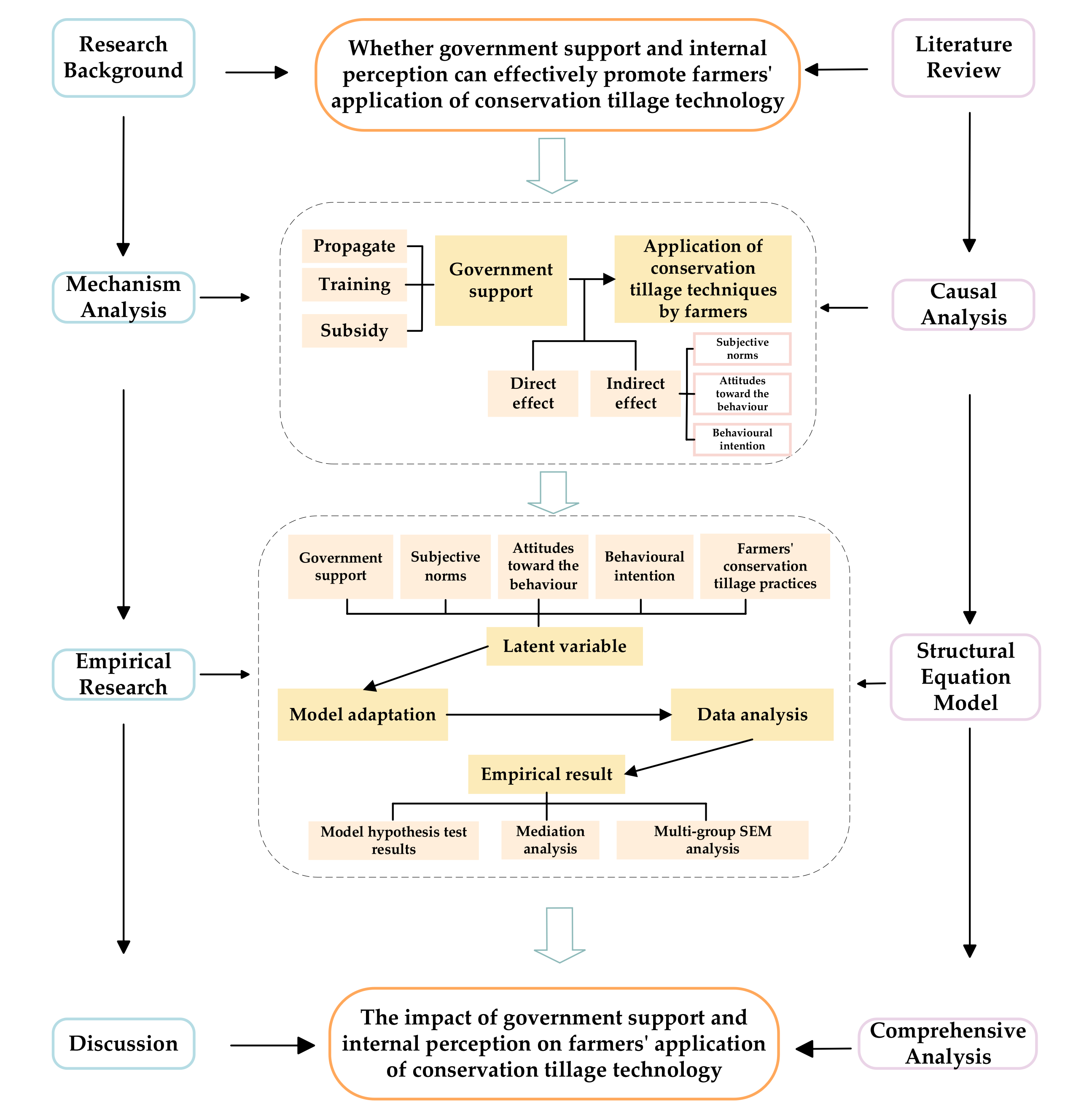

FIGURE 1
Conceptual Framework of Government Support effect on Farmers' Adoption of Conservation Tillage Technology.

government enhance technology adoption by influencing farmers' cognitive perceptions? (4) Is the SOR theoretical model compatible with the research framework concerning the effects of government support and internal perceptions on farmers' adoption behaviour regarding conservation tillage technology? Consequently, the remainder of this paper is structured as follows: (1) Section 2 presents the theoretical analysis and research hypotheses. (2) Section 3 details the research design, including the study area and survey data. (3) Section 4 reports the empirical analysis. (4) Section 5 provides the discussion, conclusions and policy recommendations. The specific study framework is depicted in Figure 1.

2 Theoretical framework and research hypothesis

2.1 Theoretical framework

The SOR theoretical model, which originates from psychology, primarily explains how environmental stimuli influence an individual's internal psychological state, subsequently leading to corresponding behaviours responses (Mehrabian and Russell, 1974). This theoretical framework has served as a significant guiding principle across various disciplinary fields, including, but not limited to, Marketing

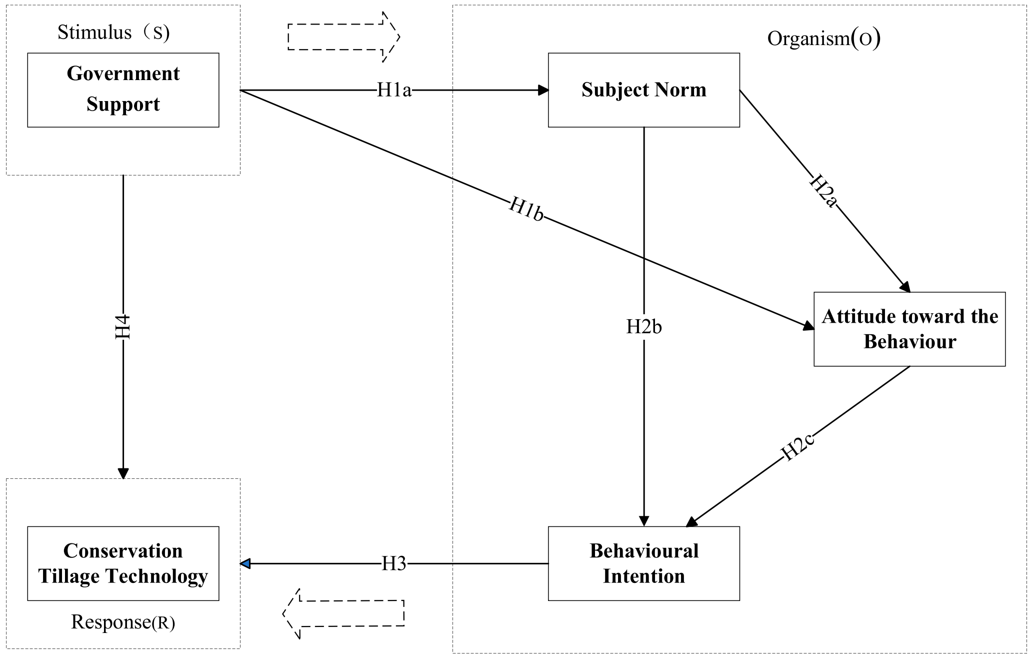

FIGURE 2
The SOR Framework for the effect of Government Support on Farmers' Adoption of Conservation Tillage Technology.

(Ying et al., 2022), Education (Liu et al., 2023), Health Behaviour (Dhir, 2022), and Environmental Psychology (Syed et al., 2023).

Although this study employs the SOR theoretical model to construct the research model, the SOR theory is not mutually exclusive but highly compatible with classic social psychology theories such as TRA and TPB. The SOR theoretical model provides an integrative umbrella paradigm capable of incorporating and reframing the core elements of TRA/TPB (Bagozzi, 1986). The 'stimulus' (S) in the SOR theoretical model can be regarded as the external antecedent influencing behavioural intention and attitude in TRA/TPB. The internal cognitive and affective processes within the 'organism' (O) directly correspond to the attitudes, subjective norms, and perceived behavioural control in TRA/TPB, while the final 'response' (R) equates to actual usage behaviour (Koo and Ju, 2010). Thus, rather than discarding TRA/TPB, this study situates their core mechanisms within a more contextually grounded 'environment-individual' interaction framework, thereby addressing the call for a 'comprehensive analysis' raised in the introduction.

The study team observed during field investigations that farmers' conservation tillage technology adoption behaviour progresses through three stages: "external environmental stimulus → internal psychological perception → action response." This observation validates the relevance of the SOR theoretical model within the context of this study and provides an analytical framework for explaining the factors influencing farmers' conservation tillage technology adoption behaviour. Therefore, this study defines "S" as government support, "O" as subjective norms, attitudes toward behaviour, and behavioural intention, and "R" as farmers' conservation tillage technology adoption behaviour. Through empirical analysis of the SOR theoretical model, this study systematically uncovers the intrinsic pathways through which government support influences farmers' technology adoption behaviour through psychological cognitive mechanisms, aiming to provide both theoretical foundations and policy insights for governments to develop more effective policy measures that promote sustainable agricultural development. The specific theoretical model is presented in Figure 2.

2.2 Justification of methods

The Structural Equation Model (SEM), commonly known as latent variable modeling, is a highly effective method rooted in factor analysis and linear regression, specifically designed to analyze complex path relationships among variables. This approach leverages the covariance matrix of variables to clearly define the direct and indirect effects of independent variables on dependent variables, facilitating a thorough exploration of intricate causal relationships. This study decisively aims to validate the direct impact of government support on farmers' adoption of conservation tillage technologies, while also examining the crucial mediating role of internal perceptions in this relationship. With its ability to simultaneously estimate multiple mediating effects, SEM is ideally suited for analyzing the interconnected pathways relevant to this research. Therefore, SEM has been determined as the appropriate method for our analysis.

Measurement Model:

$$X = \Lambda x \xi + \delta \tag{1}$$

$$Y = \Lambda y \xi + \varepsilon \tag{2}$$

Structural Model:

$$\eta = B\eta + \Gamma\xi + \zeta \tag{3}$$

In this context (Equations 1–3), X and Y are observed variables, with X being exogenous and Y being endogenous. The symbols δ and ε represent the measurement errors associated with these observed variables. The terms Λx and Λy denote the factor loadings of the indicator variables X and Y, respectively. Additionally, η and ξ are endogenous and exogenous latent variables, respectively. The matrices B and Γ represent the effect coefficients corresponding to these variables, while ζ signifies the error term in the structural equation.

2.3 Research hypothesis

2.3.1 Government support and internal perception

Only when the government genuinely acknowledges and effectively addresses the rights and interests of farmers—by considering their practical constraints in agricultural practices through appropriate policy support—can it successfully stimulate farmers' internal motivation as an "organism" (which includes subjective norms, attitudes toward behaviour, and behavioural intention). This, in turn, encourages them to actively engage in decision-making related to rural public affairs and to implement conservation tillage technology proactively (Lavergne et al., 2010).

Specifically, the government may implement a variety of support measures—including policy advocacy, economic subsidies, and technical training (for example, promoting Potato-Jade-Bean Sets of Planting Technology, Straw Mulching, and Organic Fertilizer Application)—to enhance the cognitive capacity and application proficiency of farmers regarding conservation tillage technology, while simultaneously reinforcing their intrinsic motivation to engage in rural environmental governance and ecological protection (Wijaya and Kokchang, 2023). This, in turn, exerts a positive influence on the psychological cognitive mechanisms of farmers. In light of this, this study posits the following theoretical hypotheses:

Hypothesis 1. Government Support directly and positively affects Internal Perception

Hypothesis 1a. Government Support positively influences Subjective Norms.

Hypothesis 1b. Government Support positively influences Attitudes Toward Behaviour.

Hypothesis 1c. Subjective Norms mediate the relationship between Government Support and Attitudes Toward Behaviour.

Hypothesis 1d. Subjective Norms mediate the relationship between Government Support and Behavioural Intention.

Hypothesis 1e. Attitudes Toward Behaviour mediate the relationship between Government Support and Behavioural Intention.

Hypothesis 1f. Subjective Norms and Attitudes Toward Behaviour mediate the relationship between Government Support and Behavioural Intention through a chain mediation effect.

2.3.2 Internal perception

Subjective norms refers to the social pressure or external influence perceived by farmers during the adoption of conservation tillage technology (e.g., Potato-Jade-Bean Sets of Planting Technology, Straw Mulching, and Organic Fertilizer Application), originating from social reference groups such as relatives and neighbors, government policy support, and technical training (Wan et al., 2017). According to Ajzen's Theory of Planned Behaviour, individual behavioural decisions are frequently influenced by the attitudes of significant others or groups (Ajzen, 2011). Research conducted by Ahmed et al. in the domain of domestic waste sorting has confirmed that when individuals perceive demonstration effects and positive feedback from social groups, their probability of adopting the behaviour significantly increases (Khan et al., 2019). Chow and Chan further indicated that normative pressure generated by social reference groups can effectively strengthen individuals' behavioural intentions (Chow and Chan, 2008). Existing studies demonstrate that subjective norms significantly facilitates farmers' willingness to adopt conservation tillage technology.

Attitudes toward behaviour reflects farmers' positive or negative evaluations of the implementation of conservation tillage technology, which stem from their expected perceptions of behavioural outcomes. (Bilic, 2005; Ateş, 2020). The study suggests that the attitudes toward behaviour is a crucial antecedent variable in predicting farmers' willingness to adopt technology, and the positivity level of this attitude is significantly and positively correlated with the strength of behavioural intention.

Behavioural intention denotes the degree of an individual's readiness to participate in a particular behaviour, which reflects their psychological disposition and determination to undertake such action. In this study, it specifically refers to the extent of farmers' willingness to consistently adopt conservation tillage technology. TPB accentuates (Ateş, 2020) that behavioural intention is collaboratively influenced by subjective norms and attitude towards the behaviour, functioning as the most direct cognitive variable for forecasting actual behaviour. Consequently, the following hypotheses are articulated:

Hypothesis 2. Subjective Norms and Attitudes Toward Behaviour directly and positively influence Behavioural Intention.

Hypothesis 2a. Subjective Norms positively influence Attitudes Toward Behaviour.

Hypothesis 2b. Subjective Norms positively influence Behavioural Intention.

Hypothesis 2c. Attitudes Toward Behaviour positively influences Behavioural Intention.

Hypothesis 2d. Attitudes Toward Behaviour mediates the relationship between Subjective Norms and Behavioural Intention.

2.3.3 Behavioural intention and farmers' conservation tillage technology adoption behaviour

In order to conduct a comprehensive analysis of the mechanisms underlying farmers' adoption behaviour concerning conservation tillage technology, scholars have established several influential theoretical frameworks. Among these, the TRA and the TPB are particularly noteworthy (Ajzen and Fishbein, 1977; Ajzen, 1991). These models focus on evaluating the predictive influence of psychological cognitive factors—specifically, attitude towards the behaviour, subjective norms, perceived behavioural control, and behavioural intention—on the behaviour of technology adoption. Existing literature generally characterizes conservation tillage technology adoption behaviour as the actions performed by individual farmers or groups to mitigate ecological environmental challenges (Bockarjova and Steg, 2014), thereby highlighting the significant role of individual attitudes in this decision-making process. According to the core proposition of the TRA, when farmers acknowledge the considerable advantages of conservation tillage technology, their adoption attitudes are markedly reinforced. This, in turn, improves their behavioural intention and ultimately encourages sustained adoption of the technology. Consequently, Hypothesis 3 is proposed:

Hypothesis 3. Farmers' Behavioural Intention have a positive effect on Conservation Tillage Technology.

2.3.4 Government support and farmers' conservation tillage technology adoption behaviour

From the perspective of exogenous factors, external interventions primarily characterized by governmental support play a crucial role in influencing farmers' adoption behaviour regarding conservation tillage technology. A study demonstrates that technical training can significantly improve farmers' proficiency with technologies such as conservation tillage, thereby mitigating the negative environmental externalities associated with agricultural production (Goodhue et al., 2010). According to the "rational economic agent" hypothesis, it has been shown that economic incentives effectively promote the adoption of conservation tillage technology among farmers (Ataei et al., 2022). Further studies evaluating the environmental and financial effects of government support measures (e.g., promoting organic fertilizer application) confirm their efficacy in facilitating the adoption of conservation tillage technology (Jensen, 2002). Multidimensional government support facilitates the development of farmers' knowledge literacy by diminishing information acquisition costs, enhancing the effectiveness of information, and expediting the cognition and adoption of technology, ultimately propelling the behaviour associated with the adoption of conservation tillage technology (Zhang et al., 2019).

It is essential to recognize that the organizational effectiveness of grassroots government officials, as primary implementers of technology extension, has a direct impact on farmers' cognitive evaluation systems related to conservation tillage technology (Huang, 2016). Effective communication between government officials and agricultural producers can significantly enhance the perceived benefits that farmers derive from adopting conservation tillage technology.

By enhancing the demonstration and leadership roles of grassroots organizations, along with improving the technology extension service system, farmers' participation in conservation tillage practices can be effectively incentivized, thereby promoting the development of a community focused on agricultural environmental governance (Williams et al., 1992). Based on the above analysis, this study proposes the following hypotheses:

Hypothesis 4. Government Support positively affects conservation tillage Technology

Hypothesis 4a. Subjective Norms and Behavioural Intention mediate the relationship between Government Support and Conservation Tillage Technology through a chain-mediated effect.

Hypothesis 4b. Attitudes Toward Behaviour and behavioural intention mediate the relationship between Government Support and Conservation Tillage Technology through a chain mediation effect.

Hypothesis 4c. Subjective Norms, Attitudes Toward Behaviour, and behavioural intention mediate the relationship between Government Support and Conservation Tillage Technology through a chain mediation effect.

The SEM model depicting the relationships among Government Support, Subjective Norms, Attitudes Toward Behaviour, behavioural intention, and Conservation Tillage Technology is shown in Figure 3.

3 Research design

3.1 Study area

Enshi City (Figure 4) is located in the mountainous southwestern region of Hubei Province, characterized by a typical subtropical monsoon climate. This area, with an average altitude of 1,000 m, experiences an annual mean temperature of 16 °C and approximately 1,400 mm of precipitation. The unique topography, climatic conditions, and acidic soils collectively establish a cultivation pattern dominated by dryland agriculture. According to the latest statistics, the total cultivated land area of the city is approximately 260,000 ha, with dryland constituting over 70% (approximately 190,000 ha), wherein potato and maize are the primary staple crops. Influenced by the mountainous terrain, the cultivated land exhibits significant fragmentation. Traditional farming practices, such as slope planting and excessive application of chemical fertilizers, have exacerbated soil erosion and structural degradation, culminating in agricultural non-point source pollution and a sustained decline in soil fertility.

In response to these challenges, local governments are actively promoting conservation tillage technology, which encompasses practices such as land rotation and no-till or reduced tillage systems. By the year 2023, the coverage of soil testing based formulated fertilization technology has surpassed 90%, while the rates of unified prevention and control, as well as green pest

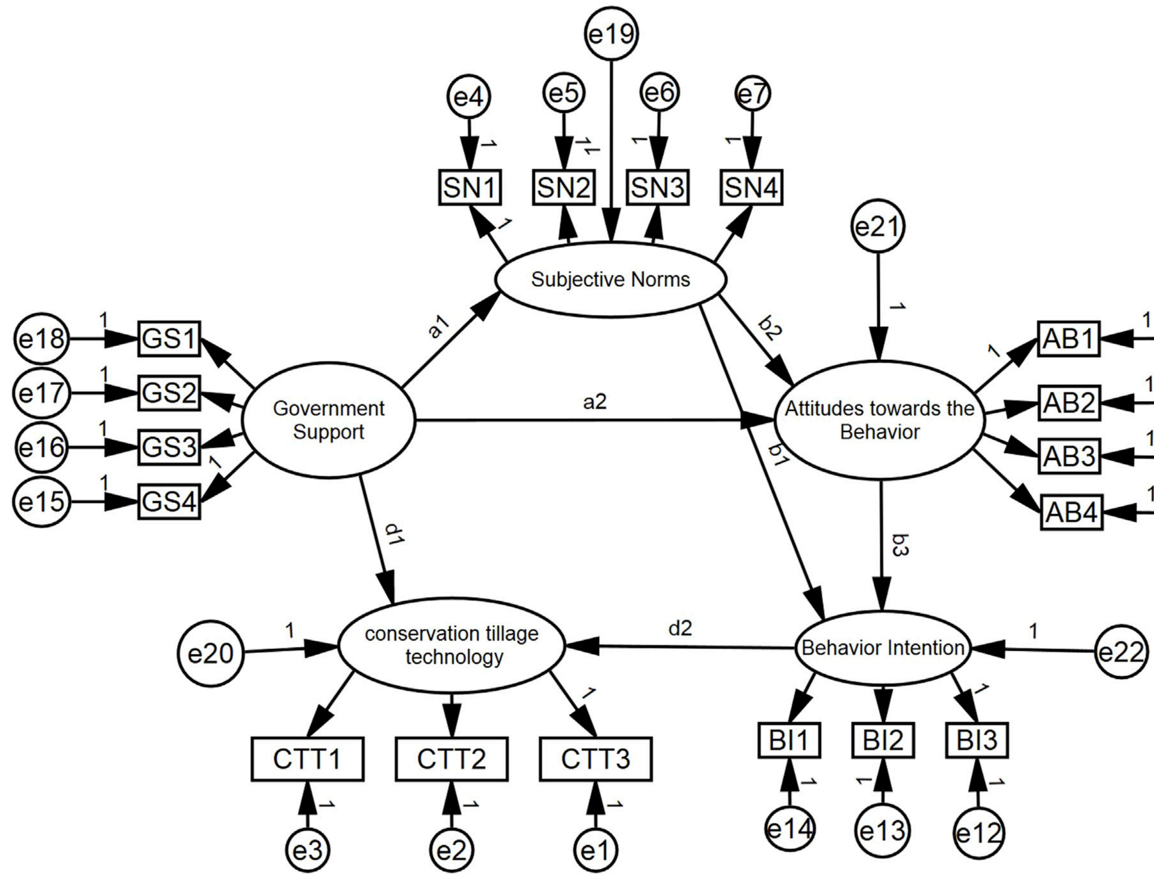

FIGURE 3
SEM model of the effect of Government Support on Farmers' Conservation Tillage Technology adoption behaviour.

management for major crops, have attained 40% and 32% respectively. Additionally, pesticide usage is exhibiting an annual decline rate of 9.68%. Considering the representative geographical characteristics of the region and the outcomes associated with the promotion of conservation tillage technology, this study has chosen Enshi City, Hubei Province as the study area, focusing on mountainous potato-growing farmers in order to investigate the adoption status and influencing factors of specific conservation practices, including Pota-to-Jade-Bean Sets of Planting Technology, organic fertilizer application, and straw mulching.

3.2 Questionnaire design

3.2.1 Question design

This study employed a structured questionnaire design that comprises three sections: (1) Respondents' socio-economic characteristics, which cover fundamental variables such as age, gender, educational attainment, cultivated land area, and agricultural income level. (2) The current status of conservation tillage technology adoption focuses on behavioural indicators, including types of adoption and frequency of usage. (3) The influencing factors of technology adoption, which measure dimensions of government support, subjective norms, attitudes toward the behaviour, behavioural intention, and farmers' conservation tillage technology adoption behaviour based on the SOR theoretical framework. All items were measured using five-point Likert scales and underwent presurvey testing that included reliability and validity verification.

3.2.2 Data sources

The research team conducted questionnaire surveys in Enshi City during December 2024. A total of 260 questionnaires were distributed, resulting in the acquisition of 245 valid questionnaires after data cleaning, thereby yielding an effective response rate of 94.23%. As illustrated in Table 1, the analysis of sample characteristics indicates that the gender distribution among respondents was balanced, with males comprising 53.1% and females 46.9%. The age composition was predominantly characterized by individuals in the prime aged workforce (31–56 years), who collectively represented 69.8%. In terms of educational attainment, 71.5% of respondents held a senior high school education or higher, signifying a robust educational foundation within the sample population.

3.3 Descriptive analysis

Based on the collected data, this study conducts descriptive statistical analysis regarding farmers' conservation tillage technology

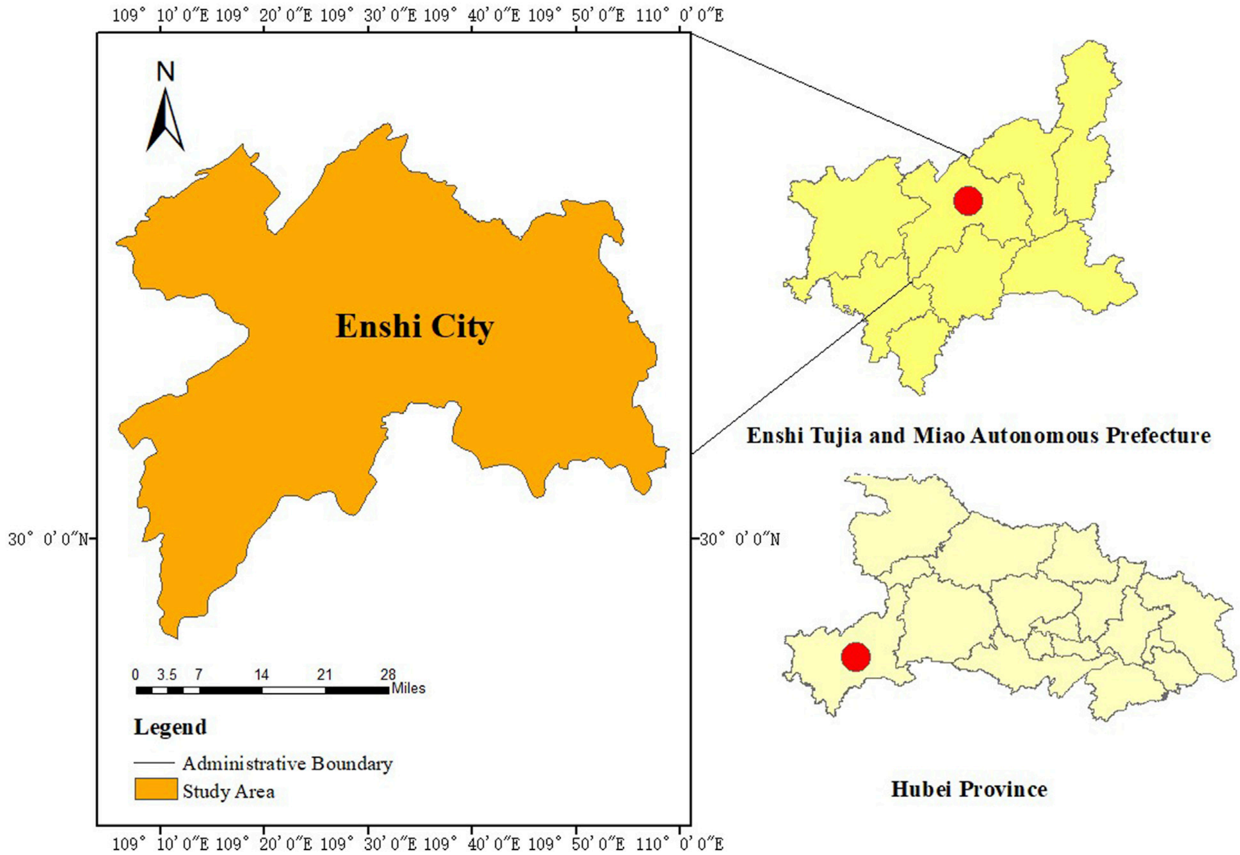

FIGURE 4
Study area of the city of Enshi.

adoption behaviour, government support, subjective norms, attitude toward the behaviour, behavioural intention, and other relevant aspects including scale measurement items.

3.3.1 The adoption behaviour of conservation tillage technology by farmers

As shown in Table 2, the mean values of each item of farmers' adoption behaviour of conservation tillage technology ranged from 3.853 to 4.037, significantly higher than the theoretical median of "3" on the five-point Likert scale. This statistical result indicates that the surveyed farmers exhibit a comparatively high adoption rate of conservation tillage technology and exhibit a positive implementation effect.

3.3.2 Government support

Table 3 data show that the mean values of government support items range from 3.914 to 3.935, significantly higher than the theoretical median of "3" on the five-point Likert scale. This finding demonstrates that farmers exhibit a high level of satisfaction with the support measures offered by the government, which encompass ecological compensation as well as training in conservation tillage technology.

3.3.3 Subjective norm

Subjective norms denotes the influence imposed by significant groups, including family members, neighbors, and governmental entities, on the specific behaviours and decision-making processes of farmers. Empirical studies indicate that when farmers recognize favorable attitudes and the actual implementation of conservation tillage technology within reference groups, their willingness to adopt such technologies considerably increases. Table 4 shows that the mean values of subjective norms measurement items range from 3.759 to 3.947, all exceeding the theoretical median of "3" on the five-point Likert scale; this indicates that sampled farmers' technology adoption behaviour is significantly influenced by subjective norms. It is therefore recommended to prioritize the cultivation of exemplary farmers and to leverage the effects of social network dissemination during the process of technology extension, thereby enhancing the impact of technology diffusion through the establishment of typical demonstration cases.

3.3.4 Attitude toward the behaviour

The mean values of attitudes toward behaviour items range from 3.653 to 3.951 as shown in Table 5, exceeding the theoretical median of "3" on the five-point Likert scale, indicating that surveyed farmers generally hold positive and proactive attitudes toward conservation tillage technology adoption behaviour.

3.3.5 Behavioural intention

Table 6 shows that the mean scores of behavioural intention items range from 3.763 to 3.784, exceeding the theoretical median of

TABLE 1 Participant demographic information (n = 245).

Variable	Option	Frequency	Proportion (%)
Gender	Male	130	53.1%
	Female	115	46.9%
Age	<30	45	18.4%
	31–43	97	39.6%
	44–56	74	30.2%
	57–69	28	11.4%
	>70	1	0.4%
Education	Below primary school	2	0.8%
	primary school	18	7.3%
	junior high school	50	20.4%
	Senior High School	83	33.9%
	University level and above	92	37.6%
Land operation area	<0.05 ha	44	18.0%
	0.05–0.25 ha	85	34.7%
	0.26–0.4 ha	48	19.6%
	0.41–0.5 ha	17	6.9%
	>0.5 ha	51	20.8%
Annual household income	<10 k	3	1.2%
	10–50 k	89	36.3%
	>50 k	153	62.4%
Annual agricultural income	<10 k	94	38.4%
	10–50 k	134	54.7%
	>50 k	17	6.9%
Number of persons engaged in agricultural labour at home	<2	110	44.9%
	2–4	132	53.9%
	>4	3	1.2%

TABLE 2 Results of farmers' Conservation Tillage Technology.

Dimension	Item	Dimension average	Mean value	β-value	Minimum	Maximum
CTT	I frequently use potato - jade - bean interplanting technology in agricultural production. (CTT1)	3.959	3.988	0.510	1.000	5.000
	The fertilizer I use in the agricultural production process is an organic fertilizer that has a protective effect on the farmland. (CTT2)		4.037	0.533	1.000	5.000
	I have frequently used straw mulching technology in agricultural production. (CTT3)		3.853	0.841	1.000	5.000

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

"3", indicating surveyed farmers hold high behavioural intention toward conservation tillage technology adoption.

The analysis of dimensional mean scores indicates that the adoption behaviour of farmers concerning Conservation Tillage Technology (Dimension Average = 3.959) and Government Support (Dimension Average = 3.976) exhibits the highest levels of recognition, followed by Subjective Norms (Dimension Average = 3.822). Although the Attitudes Toward Behaviour (Dimension

TABLE 3 Results of government support.

Dimension	Item	Dimension average	Mean value	β-value	Minimum	Maximum
GS	I am pleased with the government's policy of subsidizing CTT (GS1)	3.976	3.935	0.697	1	5
	I will actively participate in the CTT training conducted by professionals in government departments (GS2)		3.935	0.758	1	5
	I am very concerned about policies regarding CTT (GS3)		3.914	0.725	1	5
	Through government publicity, training, and subsidies, I believe that adopting CTT is a very scientific approach to development. (GS4)		4.118	0.693	1	5

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

TABLE 4 Results of subjective norm.

Dimension	Item	Dimension average	Mean value	β-value	Minimum	Maximum
SN	Through communication and learning with friends, family and neighbors, I can learn about and CTT (SN1)	3.822	3.759	0.723	1	5
	Through the government's simple propaganda and guidance, I am confident that I can understand, master and apply CTT (SN2)		3.759	0.772	1	5
	People around me are using CTT. I will use CTT. (SN3)		3.947	0.728	1	5
	I will be influenced by policy to adopt CTT. (SN4)		3.824	0.67	1	5

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

TABLE 5 Results of attitude toward the behaviour.

Dimension	Item	Dimension average	Mean value	β-value	Minimum	Maximum
AB	I think the use of CTT can improve the environment. (AB1)	3.780	3.812	0.697	1	5
	I believe that the use of CTT can save money and increase income. (AB2)		3.653	0.774	1	5
	In my opinion, the use of CTT can reduce the input of human and material resources. (AB3)		3.702	0.806	1	5
	CTT is easy to apply and I would consider adopting it. (AB4)		3.951	0.684	1	5

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

TABLE 6 Results of behaviour intention.

Dimension	Item	Dimension average	Mean value	β-value	Minimum	Maximum
BI	I would be willing to adopt CTT in the future. (BI1)	3.771	3.763	0.718	1	5
	I would want to adopt CTT in the long term. (BI2)		3.784	0.86	1	5
	I am willing to participate in activities related to CTT. (BI3)		3.767	0.816	1	5

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

Average = 3.771) and Behavioural Intention (Dimension Average = 3.767) are comparatively lower, they nonetheless surpass the theoretical median of "3". In accordance with the evaluation criteria of the five-point Likert scale, scores within the range of 3.5–5 points signify high recognition (Williams et al., 1992), all dimensional measures attain relatively elevated levels of recognition,

TABLE 7 Reliability and validity analysis.

Dimension	Variables (α = 0.878; KMO = 0.863; Bartlett's = 0)	β-value	AVE	CR	Cronbach's α
CTT	CTT1, CTT2, CTT3	0.51, 0.533, 0.841	0.417	0.670	0.654
SN	SN1, SN2, SN3, SN4	0.723, 0.772, 0.728, 0.67	0.524	0.815	0.815
AB	AB1, AB2, AB3, AB4	0.697, 0.774, 0.806, 0.806	0.551	0.830	0.828
BI	BI1, BI2, BI3	0.718, 0.86, 0.816	0.640	0.842	0.841
GS	GS1, GS2, GS3, GS4	0.697, 0.758, 0.725, 0.693	0.517	0.810	0.810

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

TABLE 8 Correlation coefficient matrix of the core variables.

	GS	AB	SN	BI	CTT
GS	0.719				
AB	0.413***	0.724			
SN	0.468***	0.576***	0.742		
BI	0.264***	0.454***	0.484*	0.800	
CTT	0.438***	0.261***	0.289***	0.332**	0.646***

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

thus corroborating the commendable reliability and validity of the questionnaire in effectively reflecting farmers' cognitions and attitudes regarding conservation tillage technology.

4 Results and analysis

4.1 Reliability and validity analysis

This study analyzed 245 valid questionnaires and Table 7 shows that: (1) The overall Cronbach's α coefficient was 0.878, approaching 0.9, indicating good reliability of the questionnaire. The Cronbach's α coefficients for all dimensions were approximately or exceeded 0.7, demonstrating high internal consistency (Nunnally, 1975). (2) Exploratory factor analysis yielded a KMO (Kaiser-Meyer-Olkin) value of 0.863, nearing 0.9, with Bartlett's test of sphericity showing significance at <0.01, meeting factor analysis requirements. (3) Confirmatory factor analysis conducted via AMOS 26.0 software revealed composite reliability values exceeding 0.6 across all dimensions, and standardized factor loadings for corresponding variables all surpassed 0.5, confirming high reliability of the questionnaire data.

In Table 8, discriminant validity was tested according to Fornell and Larcker's method (Fornell and Larcker, 1981). The square roots of the Average Variance Extracted (AVE) for each variable are presented on the diagonal, whereas the absolute values of the correlation coefficients among the variables are depicted below the diagonal. The square roots of AVE surpass the absolute values of the correlation coefficients between all variables, thereby indicating that the scale data exhibit strong discriminant validity and convergent validity. In Table 7, the AVE value for conservation tillage technology is 0.417, which is below the standard threshold of 0.5. However, according to Fornell and Larcker, if the AVE is less than 0.5 but the CR exceeds 0.6, an AVE value of 0.4 can still be considered acceptable. Thus, the AVE value of conservation tillage technology meets the established criteria.

4.2 Structural equation model testing

4.2.1 Model fit test

As shown in Table 9, the fit indices of the measurement model were examined (Anderson and Gerbing, 1992). The χ^2/df ratio was 1.593, which satisfies the criterion of <3. The Goodness of Fit Index (GFI) was 0.916, the Tucker-Lewis Index (TLI) was 0.945, the Incremental Fit Index (IFI) was 0.955, and the Comparative Fit Index (CFI) was 0.954, all exceeding the threshold of >0.9. The Root Mean Square Error of Approximation (RMSEA) was 0.049, which is below the acceptable limit of <0.08. These results indicate a high level of model fit and satisfactory configurational validity.

4.2.2 Hypothesis testing

After verifying the model fit indices, the fit indices of the structural model met the evaluation criteria. Based on the confirmed fit indices, we further examined the results of hypothesis testing for the structural model. As shown in Table 10, the p-values for the seven hypothesized paths were all <0.05, indicating significant results. Specifically, the paths "Government Support → Subjective Norms", "Government Support → Attitudes Toward Behaviour", "Subjective Norms → Attitudes Toward Behaviour", "Subjective Norms → Behavioural Intention", "Attitudes Toward Behaviour → Behavioural Intention", "behavioural intention → Conservation Tillage Technology", and "Government Support → Conservation Tillage Technology" were all

TABLE 9 Model fit indices inspection.

Index of goodness of fit	Reduced fit index			Value added fit index		Absolute fit indices		
	χ2/df	PGFI	PNFI	CFI	IFI	TLI	RMSEA	GFI
Standard	$1<\chi^2/df<3$	>0.5	>0.5	>0.9	>0.9	>0.9	<0.08	>0.9
Model	1.593	0.685	0.742	0.954	0.955	0.945	0.049	0.916
	Support	Support	Support	Support	Support	Support	Support	Support

TABLE 10 Hypothesis testing.

Hypothesis	Path	Regression weights	β-value	S.E.	C.R.	P-value	Significant or not	Test result
H1a	GS→SN	0.482	0.413	0.097	4.944	***	Yes	Support
H1b	GS→AB	0.331	0.278	0.095	3.493	***	Yes	Support
H2a	SN→AB	0.471	0.461	0.088	5.344	***	Yes	Support
H2b	SN→BI	0.314	0.262	0.111	2.837	*	Yes	Support
H2c	AB→BI	0.391	0.333	0.109	3.578	***	Yes	Support
H3	BI→CTT	0.214	0.233	0.071	2.997	**	Yes	Support
H4	GS→CTT	0.483	0.376	0.108	4.485	***	Yes	Support

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

TABLE 11 Model fit summary of multiple-group SEM.

Model	χ^2	df	χ^2/df	RMSEA	IFI	TLI	CFI	PGFI	PNFI
Standard			<3	<0.08	>0.9	>0.9	>0.9	>0.5	>0.5
Unconstrained	351.766	256	1.374	0.039	0.944	0.931	0.943	0.647	0.687
Measurement weights	362.141	269	1.346	0.038	0.945	0.936	0.944	0.677	0.718
Structural weights	377.01	276	1.366	0.039	0.94	0.933	0.939	0.69	0.73
Structural covariances	378.703	277	1.367	0.039	0.94	0.933	0.939	0.692	0.731
Structural residuals	383.078	281	1.363	0.039	0.94	0.933	0.939	0.701	0.74
Measurement residuals	400.204	299	1.338	0.037	0.94	0.938	0.939	0.74	0.779

statistically significant. Thus, hypotheses H1a, H1b, H2a, H2b, H2c, H3, and H4 were supported. This demonstrates that government support influences farmers' internal perceptions, which in turn affects their willingness to adopt conservation tillage practices. Additionally, the farmers' own perceptions also play a significant role in their adoption of conservation tillage technology.

4.2.3 Multi-group confirmatory factor analysis

The sample data (N = 245) were divided into "male" (N = 130) and "female" (N = 115) groups. Multi-group CFA was conducted to test the model's applicability across gender groups with equivalent characteristics. The unconstrained model was compared with restricted models (measurement weights, structural weights, structural covariances, structural residuals, and measurement residuals). $\Delta\chi^2$, Δp-value, and IFI, CFI from Tables 11, 12 demonstrated that the second-order SEM passed metric invariance tests, confirming its cross group applicability for both genders.

Multigroup analysis was estimated using "Critical ratios for differences". As illustrated in Table 13, the results indicate that the path coefficient difference for "Attitudes Toward Behaviour → Behavioural Intention" had |CR| <1.96, demonstrating significant differences between male and female groups on this path. Comparing path coefficients revealed that the influence of AB on behavioural intention was lower in the male group (β = 0.316) than in the female group (β = 0.332). This suggests that within the cognitive domain of farmers' adoption behaviour of conservation tillage technology, females adopt conservation tillage technology more proactively; therefore, enhancing male farmers' engagement and motivation in adopting conservation tillage technology is recommended.

TABLE 12 Invariance test of multiple-group SEM.

Model	△χ²	△df	△P-value	△IFI	△TLI	△CFI	△PGFI	△PNFI
Measurement weights	10.375	13	0.663	0.001	−0.008	0	−0.267	−0.226
Structural weights	25.244	20	0.192	−0.004	−0.011	−0.005	−0.254	−0.214
Structural covariances	26.937	21	0.173	−0.004	−0.011	−0.005	−0.252	−0.213
Structural residuals	31.312	25	0.179	−0.004	−0.011	−0.005	−0.243	−0.204
Measurement residuals	48.438	43	0.263	−0.004	−0.006	−0.005	−0.204	−0.165

TABLE 13 Estimation results of different groups.

Path	Standardized regression weights		|CR|	differ (|CR| <1.96)
	Male	Female		
GS→SN	0.354***	0.465***	|-0.527|	No
GS→AB	0.27***	0.283***	|-0.72|	No
SN→AB	0.527***	0.42***	|-0.505|	No
SN→BI	0.284*	0.238*	|-1.275|	No
AB→BI	0.316***	0.332***	|3.14|	Differ
BI→CTT	0.243*	0.246*	|-1.21|	No
GS→CTT	0.348***	0.389***	|-0.396|	No

CTT,conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

4.2.4 Mediation effect test

This study employed the Bootstrap method to test the mediating effect, with the number of Bootstrap samples set to 2000 and a confidence interval of 95%. If the 95% confidence interval for the indirect effect does not include 0, it indicates the presence of a mediating effect. As illustrated in Table 14, the Bootstrap confidence intervals for all eight mediation paths did not encompass zero, thereby indicating that all paths successfully passed the significance test. This shows that government support can indirectly impact farmers' adoption of conservation tillage technology through the mediating factor of internal perception.

Based on the mediation paths derived from Table 14, the mediation effects are synthesized as follows:

1. The mediation path "Government Support → Subjective Norms → Attitudes Toward Behaviour" showed a 95% confidence interval (0.106, 0.321) excluding zero, indicating the presence of this mediation path.
2. The mediation path "Government Support → Subjective Norms → Behavioural Intention" demonstrated a 95% confidence interval (0.019, 0.228) excluding zero, confirming its significance.
3. For the path "Government Support → Attitudes Toward Behaviour → Behavioural Intention" the 95% confidence interval (0.023, 0.205) not containing zero validated its mediating role.
4. The chain mediation path "Government Support → Subjective Norms → Attitudes Toward Behaviour → Behavioural Intention" exhibited a 95% confidence interval (0.028, 0.141) excluding zero.
5. The indirect effect through "Subjective Norms → Attitudes Toward Behaviour → Behavioural Intention" had a 95% confidence interval (0.072, 0.296) without encompassing zero.
6. The extended mediation path "Government Support → Subjective Norms → Behavioural Intention → Conservation Tillage Technology" revealed a 95% confidence interval (0.003, 0.072) excluding zero.
7. The path "Government Support → Attitudes Toward Behaviour → Behavioural Intention → Conservation Tillage Technology" showed a 95% confidence interval (0.004, 0.059) not containing zero.
8. The full chain mediation path "Government Support → Subjective Norms → Attitudes Toward Behaviour → Behavioural Intention → Conservation Tillage Technology" produced a 95% confidence interval (0.004, 0.043) excluding zero.

5 Conclusions and policy recommendations

5.1 Discussion

The research findings suggest that governments can influence farmers' adoption of conservation tillage technology through their internal perceptions. With collaborative efforts between the government and farmers, the sustainable implementation of

TABLE 14 Mediation effect test.

Hypothesis	Path	Effect size	S.E.	Bias-corrected 95%CI			Percentile 95%CI			Test result
				Lower	Upper	P-value	Lower	Upper	P-value	
H1c	GA→SN→AB	0.19	0.055	0.106	0.321	0.001	0.098	0.313	0.001	Support
H1d	GS→SN→BI	0.108	0.052	0.019	0.228	0.014	0.02	0.228	0.014	Support
H1e	GS→AB→BI	0.093	0.046	0.023	0.205	0.005	0.019	0.197	0.008	Support
H1f	GS→SN→AB→BI	0.063	0.025	0.028	0.141	0.001	0.022	0.119	0.003	Support
H2e	SN→AB→BI	0.154	0.054	0.072	0.296	0.001	0.058	0.276	0.003	Support
H4a	GS→SN→BI→CTT	0.025	0.017	0.003	0.072	0.015	0.002	0.067	0.023	Support
H4b	GS→AB→BI→CTT	0.022	0.013	0.004	0.059	0.007	0.002	0.052	0.017	Support
H4c	GS→SN→AB→BI→CTT	0.015	0.009	0.004	0.043	0.004	0.002	0.035	0.013	Support

CTT, conservation tillage technology; GS, Government Support; SN, Subjective Norms; AB, Attitudes Toward Behaviour; BI, behavioural intention.

conservation tillage technology can be achieved. This partnership not only enhances local ecological development but also helps transform "lucid waters and lush mountains" into "invaluable assets."

The government supports farmers in adopting conservation tillage technology through various channels, including publicity, training, and subsidies. The study found that government support has a significantly positive impact on farmers' adoption of this technology. This indicates that such support enhances farmers' awareness, familiarity, and satisfaction with relevant policies. As farmers become more aware, familiar, and satisfied with these policies, they are increasingly likely to approve of conservation tillage technology and have a stronger intention to adopt it. Further research suggests that when farmers receive government support and guidance, they are more proactive in adopting conservation tillage technology, which in turn promotes green agricultural development and contributes to the construction of ecological civilization.

Farmers' internal perceptions are vital for their adoption of conservation tillage technology. The strength of a farmer's behavioural intention is a key factor in determining whether they choose to adopt this technology. In general, the stronger their behavioural intention, the more likely they are to successfully implement it. Furthermore, farmers' attitudes play a mediating role between their subjective norms and behavioural intentions. This means that as more farming groups adopt conservation tillage practices, the greater the likelihood that individual farmers will approve of the technology, subsequently increasing their intention to adopt it.

Government support positively influences farmers' internal perceptions, which in turn significantly affects their adoption of conservation tillage technology. This indicates that government initiatives—such as publicity, training, and subsidies—can improve farmers' understanding, attitudes, and intentions regarding the use of conservation tillage technology, ultimately encouraging them to adopt these practices.

5.2 Conclusions

Recognizing that a singular study perspective may inadequately analyze the factors influencing farmers' adoption of conservation tillage technology, this study broadens the perspectives and theoretical frameworks involved. Guided by the research questions outlined earlier, this study seeks to address the following: (1) How does government support directly influence farmers' adoption of conservation tillage practices? (2) How does government support indirectly influence this adoption through the mediating variable of farmers' internal perceptions? (3) Is the Stimulus-Organism-Response (SOR) theoretical model suitable for examining the impact of government support and internal perceptions on farmers' adoption behaviour regarding conservation tillage practices? Using the SOR model as a foundation, this study integrates government support (S) with farmers' internal perceptions (O) to explore how government support influences their adoption behaviour (R). This analysis considers both endogenous and exogenous factors while also examining the mediating roles of subjective norms, behavioural attitudes, and behavioural intentions.

The findings indicate that: (1) government support measures, including economic incentives and awareness campaigns or training, directly encourage farmers to proactively implement conservation tillage technology. (2) By shaping farmers' internal perceptions (subjective norms, attitudes toward behaviour, and behavioural intention), government initiatives indirectly enhance their active adoption of conservation tillage technology. Driven by government advocacy and the demonstration effects of neighboring farmers, farmers' willingness to implement these practices transitions from a passive to a proactive stance, with their attitudes shift from compelled compliance to engaged participation. (3) Verification shows that the "SOR" theoretical model effectively explains the mechanism behind farmers' adoption behaviour regarding conservation tillage technology in response to government support.

5.3 Policy recommendations

5.3.1 Establish a long-term supervision mechanism

Given the gradual nature of behavioural change among farmers, it is advisable for the government to establish a regulatory framework that prioritizes guidance and education, supplemented by disciplinary measures. Such an approach would promote the voluntary adoption of conservation tillage practices through the incremental internalization of policy measures (Verplanken and Roy, 2016). Additionally, it is essential to emphasize flexibility in law enforcement during supervision to avoid policy resistance that may result from overly rigid constraints.

5.3.2 Optimize conservation tillage technology dissemination channels

Dilleen et al. utilized a method that combined semi-structured interviews with netnography to examine the role of social media in the diffusion of agricultural technologies (Dilleen et al., 2023). Their research indicates that social media serves as a vital tool for connecting farmers and fostering discussions, which helps overcome the "homogeneous" information barriers typical of traditional agricultural promotion. By enhancing farmers' awareness and trust in sustainable agricultural practices, such as conservation tillage, social media accelerates the adoption of new technologies. Therefore, it is recommended to integrate innovative media with traditional communication methods to create diverse pathways for technology diffusion. Showcasing the economic and ecological co-benefits through real-world examples can effectively address farmers' misconceptions and boost their confidence in adopting conservation tillage technology (Zhang et al., 2020a).

5.3.3 Strengthen psychological incentive mechanisms

The study substantiates the notion that internal perception serves as a crucial mediating variable in the adoption behaviour of conservation tillage technology among farmers (Wang et al., 2019). Establishing technical implementation support systems and using nonmaterial incentives to enhance awareness of environmental responsibility are recommended to continually improve farmers' behavioural intention.

5.3.4 Improve the government support system

Government support influences farmers' adoption of conservation tillage technology through two distinct direct pathways (Ngoc et al., 2024). While sustaining the current direct support measures, it is imperative for governments to prioritize the enhancement of grassroots policy implementation capacity. Additionally, the establishment of a multidimensional support system, which encompasses institutional guarantees and capacity building, is essential to avert superficial policy implementation and to effectively promote agricultural green transformation (Wu et al., 2024).

5.4 Limitations and prospects

5.4.1 Limitations in sample selection

The study data were exclusively derived from 245 farmer households situated in Enshi City, Hubei Province. While this region exemplifies the typical characteristics of mountainous eco-agriculture, the limited sample coverage may compromise the external validity of the findings. Future study endeavors should expand the sampling scope to establish crossregional comparative frameworks, thereby enhancing the generalizability of the discoveries (Aboelmaged, 2021).

5.4.2 Limitations in government support measurement

This study primarily examined fundamental government support mechanisms, including subsidies, technical training, and awareness campaigns, while inadequately incorporating a more extensive range of policy instruments, such as infrastructure development and market mechanisms. Consequently, future studies must establish more comprehensive measurement frameworks for policy support to facilitate a thorough analysis of the impacts of various policy tools on farmers' adoption of conservation tillage technology (Dipeolu et al., 2021).

5.4.3 Limitations in subjective norm measurement methodology

Subjective norms were primarily assessed through farmers' perceptions of their relatives, neighbors, and governmental policies. However, these indicators may not adequately represent the true social influences experienced during decision-making processes. Future study could employ social network analysis (SNA) tools (Martin et al., 2020) to more thoroughly examine how farmers' structural positions within networks of familial ties, kinship, and geographical connections influence the mechanisms of adopting conservation tillage technology.

Data availability statement

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

Author contributions

YM: Investigation, Supervision, Methodology, Writing – review and editing, Conceptualization, Validation, Writing – original draft, Funding acquisition. ZS: Investigation, Visualization, Conceptualization, Validation, Project administration, Software, Methodology, Formal Analysis, Writing – review and editing, Writing – original draft, Resources, Data curation.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research is supported by the National Social Science Foundation of China (Grant No. 23BGL208), the Key Research Project in Philosophy and Social Sciences of Hubei Provincial Department of Education (Grant No.23D051), and the school-level Scientific Research Project of Wuhan Polytechnic University (Grant No. 2024J07).

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2025.1656461/full#supplementary-material

References

Aboelmaged, M. (2021). E-waste recycling behaviour: An integration of recycling habits into the theory of planned behaviour. *J. Clean. Prod.* 278, 124182. doi:10.1016/j.jclepro.2020.124182

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process.* 50, 179–211. doi:10.1016/0749-5978(91)90020-t

Ajzen, I. (2011). The theory of planned behaviour: reactions and reflections. *Psychology & Health*. 26 (9), 1113–1127. doi:10.1080/08870446.2011.613995

Ajzen, I., and Fishbein, M. (1977). Attitude-behavior relations: A theoretical analysis and review of empirical research. *Psychol. Bull.* 84, 888–918. doi:10.1037//0033-2909.84.5.888

Alibeli, M. A., and Johnson, C. (2009). Environmental concern: A cross national analysis. *J. Int. cross-cultural Stud.* 3, 1–10.

Alt, M., Bruns, H., Dellavalle, N., and Murauskaite-Bull, I. (2024). Synergies of interventions to promote pro-environmental behaviors–A meta-analysis of experimental studies. *Glob. Environ. Change* 84, 102776. doi:10.1016/j.gloenvcha.2023.102776

Anderson, J. C., and Gerbing, D. W. (1992). Assumptions and comparative strengths of the two-step approach: Comment on Fornell and Yi. *Sociol. Methods and Res.* 20, 321–333. doi:10.1177/0049124192020003002

Anibaldi, R., Rundle-Thiele, S., David, P., and Roemer, C. (2021). Theoretical underpinnings in research investigating barriers for implementing environmentally sustainable farming practices: Insights from a systematic literature review. *Land* 10, 386. doi:10.3390/land10040386

Araya, T., Ochsner, T. E., Mnkeni, P. N., Hounkpatin, K., and Amelung, W. (2024). Challenges and constraints of conservation agriculture adoption in smallholder farms in sub-Saharan Africa: A review. *Int. Soil Water Conservation Res.* 12, 828–843. doi:10.1016/j.iswcr.2024.03.001

Arcury, T. A., and Christianson, E. H. (1990). Environmental worldview in response to environmental problems: Kentucky 1984 and 1988 compared. *Environ. Behav.* 22, 387–407. doi:10.1177/0013916590223004

Ataei, P., Karimi, H., Moradhaseli, S., and Babaei, M. H. (2022). Analysis of farmers' environmental sustainability behavior: the use of norm activation theory (a sample from Iran). *Arabian J. Geosciences* 15, 859. doi:10.1007/s12517-022-10042-4

Ateş, H. (2020). Merging theory of planned behavior and value identity personal norm model to explain pro-environmental behaviors. *Sustain. Prod. Consum.* 24, 169–180. doi:10.1016/j.spc.2020.07.006

Bagozzi, R. P. (1986). Attitude formation under the theory of reasoned action and a purposeful behaviour reformulation. *Br. J. Soc. Psychol.* 25, 95–107. doi:10.1111/j.2044-8309.1986.tb00708.x

Bamberg, S., Hunecke, M., and BlöBAUM, A. (2007). Social context, personal norms and the use of public transportation: Two field studies. *J. Environ. Psychol.* 27, 190–203. doi:10.1016/j.jenvp.2007.04.001

Barrett, S., and Dannenberg, A. (2014). Sensitivity of collective action to uncertainty about climate tipping points. *Nat. Clim. Change* 4, 36–39. doi:10.1038/nclimate2059

Bilal, M., and Jaghdani, T. J. (2024). Barriers to the adoption of multiple agricultural innovations: Insights from Bt cotton, wheat seeds, herbicides and no-tillage in Pakistan. *Int. J. Agric. Sustain.* 22, 2318934. doi:10.1080/14735903.2024.2318934

Bilic, B. (2005). The theory of planned behaviour and health behaviours: Critical analysis of methodological and theoretical issues. *Hellenic J. Psychol.*

Bockarjova, M., and Steg, L. (2014). Can Protection Motivation Theory predict pro-environmental behavior? Explaining the adoption of electric vehicles in the Netherlands. *Glob. Environ. change* 28, 276–288. doi:10.1016/j.gloenvcha.2014.06.010

Borges, J. A. R., Oude Lansink, A. G., Ribeiro, C. M., and Lutke, V. (2014). Understanding farmers' intention to adopt improved natural grassland using the theory of planned behavior. *Livest. Sci.* 169, 163–174. doi:10.1016/j.livsci.2014.09.014

Braito, M., Leonhardt, H., Penker, M., Schauppenlehner-Kloyber, E., Thaler, G., and Flint, C. G. (2020). The plurality of farmers' views on soil management calls for a policy mix. *Land Use Policy* 99, 104876. doi:10.1016/j.landusepol.2020.104876

Bratt, C. (1999). The impact of norms and assumed consequences on recycling behavior. *Environ. Behav.* 31, 630–656. doi:10.1177/00139169921972272

Bravo-Monroy, L., Potts, S. G., and Tzanopoulos, J. (2016). Drivers influencing farmer decisions for adopting organic or conventional coffee management practices. *Food policy* 58, 49–61. doi:10.1016/j.foodpol.2015.11.003

Chen, Y., Han, X., Lv, S., Song, B., Zhang, X., and Li, H. (2022). The influencing factors of pro-environmental behaviors of farmer households participating in understory economy: evidence from China. *Sustainability* 15, 688. doi:10.3390/su15010688

Chow, W. S., and Chan, L. S. (2008). Social network, social trust and shared goals in organizational knowledge sharing. *Inf. and Manag.* 45, 458–465. doi:10.1016/j.im.2008.06.007

Dhir, A., Kaur, P., and Nunkoo, R. (2022). Digitalization and Sustainability: Virtual Reality Tourism in a Post Pandemic World. *J. Sustain. Tour.* 31, 2564–2591. doi:10.1080/09669582.2022.2029870

Dilleen, G., Claffey, E., Foley, A., and Doolin, K. (2023). Investigating knowledge dissemination and social media use in the farming network to build trust in smart farming technology adoption. *J. Bus. and Industrial Mark.* 38, 1754–1765. doi:10.1108/jbim-01-2022-0060

Dipeolu, A. A., Ibem, E. O., Fadamiro, J. A., and Fadairo, G. (2021). Factors influencing residents' attitude towards urban green infrastructure in Lagos Metropolis, Nigeria. *Environ. Dev. Sustain.* 23, 6192–6214. doi:10.1007/s10668-020-00868-x

Doan, T. N., Nguyen, T. H., Yuki, I.-I., and Nguyen, T. H. H. (2025). The Effectiveness of Climate-smart Agriculture Practices in Coffee Production at Dlie Ya Commune in Dak Lak Province. *VNU J. Sci. Earth Environ. Sci.* 41.

Fornell, C., and Larcker, D. F. (1981). *Structural equation models with unobservable variables and measurement error: Algebra and statistics*. CA: Los Angeles, CA: Sage publications Sage.

Gao, Y., Zhao, D., Yu, L., and Yang, H. (2020). Influence of a new agricultural technology extension mode on farmers' technology adoption behavior in China. *J. Rural Stud.* 76, 173–183. doi:10.1016/j.jrurstud.2020.04.016

Goodhue, R. E., Klonsky, K., and Mohapatra, S. (2010). Can an education program be a substitute for a regulatory program that bans pesticides? Evidence from a panel selection model. *Am. J. Agric. Econ.* 92, 956–971. doi:10.1093/ajae/aaq032

Hruska, A. J. (1990). Government pesticide policy in Nicaragua 1985–1989. *Glob. Pestic. Monit.* 1, 3–5.

Huang, H. (2016). Media use, environmental beliefs, self-efficacy, and pro-environmental behavior. *J. Bus. Res.* 69, 2206–2212. doi:10.1016/j.jbusres.2015.12.031

Jahrl, I., Rudmann, C., Pfiffner, L., and Balmer, O. (2012). Motivations for the implementation of ecological compensation areas.

Jensen, B. B. (2002). Knowledge, action and pro-environmental behaviour. *Environ. Educ. Res.* 8, 325–334. doi:10.1080/13504620220145474

Kassam, A., Friedrich, T., and Derpsch, R. (2019). Global spread of conservation agriculture. *Int. J. Environ. Stud.* 76, 29–51. doi:10.1080/00207233.2018.1494927

Kay, M., Bunning, S., Burke, J., Boerger, V., Bojic, D., Bosc, P.-M., et al. (2022). *The state of the world's land and water resources for food and agriculture 2021. Systems at breaking point*. FAO.

Khan, F., Ahmed, W., and Najmi, A. (2019). Understanding consumers' behavior intentions towards dealing with the plastic waste: Perspective of a developing country. *Resour. Conservation Recycl.* 142, 49–58. doi:10.1016/j.resconrec.2018.11.020

Koo, D.-M., and Ju, S.-H. (2010). The interactional effects of atmospherics and perceptual curiosity on emotions and online shopping intention. *Comput. Hum. Behav.* 26, 377–388. doi:10.1016/j.chb.2009.11.009

Lavergne, K. J., Sharp, E. C., Pelletier, L. G., and Holtby, A. (2010). The role of perceived government style in the facilitation of self-determined and non self-determined motivation for pro-environmental behavior. *J. Environ. Psychol.* 30, 169–177. doi:10.1016/j.jenvp.2009.11.002

Li, J., and Song, Z. (2022). Dynamic impacts of external uncertainties on the stability of the food supply chain: Evidence from China. *Foods* 11, 2552. doi:10.3390/foods11172552

Li, Q., Li, H., Zhang, L., Zhang, S., and Chen, Y. (2018). Mulching improves yield and water-use efficiency of potato cropping in China: A meta-analysis. *Field crops Res.* 221, 50–60. doi:10.1016/j.fcr.2018.02.017

Li, W., Qiao, D., Hao, Q., Ji, Y., Chen, D., and Xu, T. (2024). Gap between knowledge and action: understanding the consistency of farmers' ecological cognition and green production behavior in Hainan Province, China. *Environ. Dev. Sustain.* 26, 31251–31275. doi:10.1007/s10668-024-04464-1

Lin, X., He, J., and Zhu, H. (2025). Explaining farmers' pro-environmental behaviors in rural China: A perspective of appraisal theory of emotions. *J. Rural Stud.* 114, 103584. doi:10.1016/j.jrurstud.2025.103584

Liu, P., Teng, M., and Han, C. (2020). How does environmental knowledge translate into pro-environmental behaviors? The mediating role of environmental attitudes and behavioral intentions. *Sci. total Environ.* 728, 138126. doi:10.1016/j.scitotenv.2020.138126

Liu, B., Gu, W., Yang, Y., Lu, B., Wang, F., Zhang, B., et al. (2021). Promoting potato as staple food can reduce the carbon–land–water impacts of crops in China. *Nat. Food* 2, 570–577. doi:10.1038/s43016-021-00337-2

Liu, Y., Cai, L., Ma, F., and Wang, X. (2023). Revenge buying after the lockdown: Based on the SOR framework and TPB model. *J. Retail. Consumer Serv.* 72, 103263. doi:10.1016/j.jretconser.2023.103263

Lun, R., Sauer, J., Gao, M., Yang, Y., Luo, Q., and Li, G. (2024). Does internet use improve eco-efficiency of agricultural production? Evidence from potato farmers in China. *J. Clean. Prod.* 477, 143794. doi:10.1016/j.jclepro.2024.143794

Martin, L., White, M. P., Hunt, A., Richardson, M., Pahl, S., and Burt, J. (2020). Nature contact, nature connectedness and associations with health, wellbeing and pro-environmental behaviours. *J. Environ. Psychol.* 68, 101389. doi:10.1016/j.jenvp.2020.101389

Mehrabian, A., and Russell, J. A. (1974). *An approach to environmental psychology*. the MIT Press.

Milfont, T. L., Duckitt, J., and Wagner, C. (2010). A cross-cultural test of the value–attitude–behavior hierarchy. *J. Appl. Soc. Psychol.* 40, 2791–2813. doi:10.1111/j.1559-1816.2010.00681.x

Ngoc, Q. T. K., Xuan, B. B., BöRGER, T., Hien, T. T., VAN Hao, T., Trinh, D. T., et al. (2024). Exploring fishers' pro-environmental behavioral intention and support for policies to combat marine litter in Vietnam. *Mar. Pollut. Bull.* 200, 116143. doi:10.1016/j.marpolbul.2024.116143

Ni, Y., Li, Z., Li, J., and Jian, Y. (2024). Impact of Urbanization on the Sustainable Production of Regional Specialty Food: Evidence from China's Potato Production. *Land* 13, 147. doi:10.3390/land13020147

Nunnally, J. C. (1975). Psychometric theory—25 years ago and now. *Educ. Res.* 4, 7–21. doi:10.2307/1175619

Syed, Q. R., Apergis, N., and Goh, S. K. (2023). The dynamic relationship between climate policy uncertainty and renewable energy in the US: Applying the novel Fourier augmented autoregressive distributed lags approach. *Energy* 275, 127383. doi:10.1016/j.energy.2023.127383

Tian, J., Dungait, J. A., Hou, R., Deng, Y., Hartley, I. P., Yang, Y., et al. (2024). Microbially mediated mechanisms underlie soil carbon accrual by conservation agriculture under decade-long warming. *Nat. Commun.* 15, 377. doi:10.1038/s41467-023-44647-4

Tran, T. D., Huan, D. M., Phan, T. T. H., and Do, H. L. (2023). RETRACTED ARTICLE: The impact of green intellectual capital on green innovation in Vietnamese textile and garment enterprises: mediate role of environmental knowledge and moderating impact of green social behavior and learning outcomes. *Environ. Sci. Pollut. Res.* 30, 74952–74965. doi:10.1007/s11356-023-27523-y

Verplanken, B., and Roy, D. (2016). Empowering interventions to promote sustainable lifestyles: Testing the habit discontinuity hypothesis in a field experiment. *J. Environ. Psychol.* 45, 127–134. doi:10.1016/j.jenvp.2015.11.008

Vis, B. N., Evans, D. L., and Graham, E. (2023). Engagement with urban soils part II: starting points for sustainable urban planning guidelines derived from Maya soil connectivity. *Land* 12, 891. doi:10.3390/land12040891

Wan, C., Shen, G. Q., and Choi, S. (2017). Experiential and instrumental attitudes: Interaction effect of attitude and subjective norm on recycling intention. *J. Environ. Psychol.* 50, 69–79. doi:10.1016/j.jenvp.2017.02.006

Wang, Y., Liang, J., Yang, J., Ma, X., Li, X., Wu, J., et al. (2019). Analysis of the environmental behavior of farmers for non-point source pollution control and management: An integration of the theory of planned behavior and the protection motivation theory. *J. Environ. Manag.* 237, 15–23. doi:10.1016/j.jenvman.2019.02.070

Whitaker, S. H. (2024). The impact of government policies and regulations on the subjective well-being of farmers in two rural mountain areas of Italy. *Agric. Hum. Values* 41, 1791–1809. doi:10.1007/s10460-024-10586-z

Wijaya, D. I., and Kokchang, P. (2023). Factors influencing generation Z's pro-environmental behavior towards Indonesia's energy transition. *Sustainability* 15, 13485. doi:10.3390/su151813485

Williams, D. R., Patterson, M. E., Roggenbuck, J. W., and Watson, A. E. (1992). Beyond the commodity metaphor: Examining emotional and symbolic attachment to place. *Leis. Sci.* 14, 29–46. doi:10.1080/01490409209513155

Williamson, K., Satre-Meloy, A., Velasco, K., and Green, K. (2018). *Climate change needs behavior change: Making the case for behavioral solutions to reduce global warming*. Rare.

Wu, J., Wang, X., Ramkissoon, H., Wu, M.-Y., Guo, Y., and Morrison, A. M. (2024). Resource mobilization and power redistribution: The role of local governments in shaping residents' pro-environmental behavior in rural tourism destinations. *J. Travel Res.* 63, 1442–1458. doi:10.1177/00472875231191983

Xie, H., and Huang, Y. (2021). Influencing factors of farmers' adoption of pro-environmental agricultural technologies in China: Meta-analysis. *Land use policy* 109, 105622. doi:10.1016/j.landusepol.2021.105622

Yang, X., Zhou, X., and Deng, X. (2022). Modeling farmers' adoption of low-carbon agricultural technology in Jianghan Plain, China: An examination of the theory of planned behavior. *Technol. Forecast. Soc. Change* 180, 121726. doi:10.1016/j.techfore.2022.121726

Ying, T., Tang, J., Ye, S., Tan, X., and Wei, W. (2022). Virtual reality in destination marketing: telepresence, social presence, and tourists' visit intentions. *J. Travel Res.* 61, 1738–1756. doi:10.1177/00472875211047273

Yu, L., Chen, C., Niu, Z., Gao, Y., Yang, H., and Xue, Z. (2021). Risk aversion, cooperative membership and the adoption of green control techniques: evidence from China. *J. Clean. Prod.* 279, 123288. doi:10.1016/j.jclepro.2020.123288

Zhang, B., Lai, K.-H., Wang, B., and Wang, Z. (2019). From intention to action: How do personal attitudes, facilities accessibility, and government stimulus matter for household waste sorting? *J. Environ. Manag.* 233, 447–458. doi:10.1016/j.jenvman.2018.12.059

Zhang, L., Ruiz-Menjivar, J., Luo, B., Liang, Z., and Swisher, M. E. (2020a). Predicting climate change mitigation and adaptation behaviors in agricultural production: A comparison of the theory of planned behavior and the Value-Belief-Norm Theory. *J. Environ. Psychol.* 68, 101408. doi:10.1016/j.jenvp.2020.101408

Zhang, Y., Long, H., Li, Y., Ge, D., and Tu, S. (2020b). How does off-farm work affect chemical fertilizer application? Evidence from China's mountainous and plain areas. *Land Use Policy* 99, 104848. doi:10.1016/j.landusepol.2020.104848