frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 21 January 2026
DOI 10.3389/fsufs.2025.1633132

OPEN ACCESS

EDITED BY
Enoch Kikulwe,
Alliance Bioversity International and CIAT, Kenya

REVIEWED BY
Vahid Karimi,
Tarbiat Modares University, Iran
Yibei Guo,
Henan University, China

*CORRESPONDENCE
Yanzhong Huang
huangyanzhong@wit.edu.cn

RECEIVED 22 May 2025
REVISED 03 December 2025
ACCEPTED 08 December 2025
PUBLISHED 21 January 2026

CITATION
Shang Y, Huang Y and Zhang Y (2026) Risk perception, risk attitude, and adoption of water-saving irrigation technology in China—from the perspective of risk reduction. *Front. Sustain. Food Syst.* 9:1633132.
doi: 10.3389/fsufs.2025.1633132

Risk perception, risk attitude, and adoption of water-saving irrigation technology in China—from the perspective of risk reduction

Yan Shang, Yanzhong Huang* and Yan Zhang

School of Law and Business, Wuhan Institute of Technology, Wuhan, China

Farmers can better withstand extreme drought risks by actively adopting water-saving irrigation technologies (WSIT). To increase farmers' adoption of WSIT, this paper, based on the survey data of 469 households in Heilongjiang Province, Liaoning Province, and Inner Mongolia Autonomous Region from 2019, uses the Logit model to deeply explore the impact of risk perception and risk attitude on the adoption of WSIT by farmers from the perspective of risk reduction. First, using empirical analysis, this study examines the effects of technological risk perception, drought risk perception, and risk attitude on farmers' adoption of WSIT. Secondly, this paper further analyzes the differences in the adoption of WSIT among farmers of different scales. Finally, this paper explores how risk attitude moderates the relationship between risk perception and farmers' adoption of WSIT. The research results indicate that technological risk perception has a significantly negative impact on farmers' adoption of WSIT. Drought risk perception and risk attitude have a significantly positive impact on farmers' adoption of WSIT. The interaction term between technological risk perception and risk preference indicates that risk preference significantly weakens the negative effect of technological risk perception on farmers' WSIT adoption. Therefore, in promoting WSIT, efforts should be made to enhance the popularization of WSIT functions, improve the accuracy of risk perception, increase farmers' understanding of the drought-resistance function of WSIT, and alleviate their concerns about technical risks. Through the above methods, farmers are guided in actively adopting WSIT, thereby enhancing their ability to withstand extreme droughts.

KEYWORDS

agricultural risk, risk attitude, risk perception, risk reduction, water-saving irrigation technology

1 Introduction

Water-saving irrigation technology (WSIT) is widely recognized as a crucial approach to addressing global water scarcity and promoting sustainable agricultural development (Zou et al., 2012). It encompasses techniques such as drip irrigation, micro-sprinkler irrigation, subsurface irrigation, and intelligent irrigation systems, etc., which enhance the efficiency of water, fertilizer, and pesticide use, reduce resource inputs, and increase crop yields (Singh et al., 2024). However, WSIT implementation may also induce hydrological changes-including alterations in surface runoff, soil moisture dynamics, groundwater recharge, and salt transport-that can potentially affect regional ecological security (Xu et al., 2010; Du et al., 2011; Singh et al., 2024; Gabiri et al., 2018).

In the existing studies on the adoption of WSIT in China, scholars have delved deeply into the multiple factors affecting farmers' adoption decisions. There has been a notable shift from the identification of single driving factors to the analysis of interaction and regulatory mechanisms among these factors. For instance, the studies by Liu H. et al. (2025), Liu Y. et al. (2025) and Dai et al. (2015) have shown that factors like farmers' planting scale, experience, and ecological awareness have a positive impact on their willingness to pay and the probability of adoption. Conversely, technical complexity and investment costs act as deterrents. Moreover, research has emphasized the crucial role of farmers' psychological cognition. Wang et al. (2024) found that perceived ease of use significantly promotes adoption behavior, while Xiuling et al. (2023) pointed out that risk aversion significantly inhibits adoption, though technical training can effectively mitigate this negative impact. Additionally, the influence of external environment and social networks has been highly regarded. Zhang and Song (2024) empirical study demonstrated that government support significantly increases farmers' adoption probability, especially for those with weaker environmental-friendly intentions. Social interaction has also been proven to be an important channel for technology diffusion. The studies by Wang and Xu (2024) and Mu et al. (2024) both emphasized that the neighborhood effect promotes technology adoption by reducing information costs and providing demonstrations, and this effect varies among different characteristics of farmers.

However, in international research, WSIT are not only widely discussed as a new technology by scholars (Belaidi et al., 2022; Salhi et al., 2012; Foster and Rosenzweig, 2010; Zhang and Song, 2024). Beyond its technical function, WSIT serves as a risk mitigation tool that can reduce the frequency and severity of drought losses (Suchato et al., 2022). As drought risks increase, the role of WSIT in agricultural risk management has become more prominent (Hanger-Kopp and Palka, 2020, 2022; Finger et al., 2011; Tang et al., 2016; Ricart et al., 2024). Although WSIT has been widely promoted, farmers ultimately decide the timing and amount of irrigation. While this technology increases agricultural production costs, it does not necessarily lead to a significant rise in food prices. Therefore, adoption depends not only on technical attributes but also on risk reduction efficacy—that is, whether WSIT can effectively help farmers withstand agricultural shocks and minimize losses (Vågsholm et al., 2020; Garcia et al., 2020).

Farmers' risk perception and attitude are the key factors affecting their adoption of risk reduction tools. Some scholars have examined the individual effects of risk perception or risk attitude on farmers' risk management behaviors (Menapace et al., 2016; Sitkin and Weingart, 1995; Hellerstein et al., 2013). While some studies indicate that risk attitude has greater predictive power than risk perception (van Winsen et al., 2016). Farmers' perception of agricultural risks will significantly influence their adoption of WSIT. Studies have shown that farmers with more serious perception of drought risk are more willing to adopt WSIT (Hatch et al., 2022; Asare-Nuamah et al., 2022; Wang et al., 2018; Mu et al., 2024). Koundouri et al. (2005) pointed out that risk attitude affected the possibility of farmers adopting irrigation technology, which provided evidence for farmers to invest in irrigation technology to prevent related agricultural risks. Risk-averse farmers will be more active in adopting WSIT to conserve water and reduce production (yield) risk (Torkamani and Shajari, 2008).

In summary, existing research on water-saving irrigation technology (WSIT) can be broadly categorized into two streams. The first treats WSIT as a generic innovation, focusing on how farmers' individual characteristics, household conditions, and external environmental factors influence adoption decisions. The second emphasizes its role in mitigating drought risk, examining the individual effects of either risk perception or risk attitude on adoption behavior. However, current literature has yet to systematically integrate the dual attributes of WSIT—as both an innovative technology and a risk-coping tool—within a unified analytical framework. This limitation hinders a comprehensive understanding of the mechanisms underlying farmers' technology adoption decisions.

To address this research gap, this study employs survey data collected from farmers in Inner Mongolia Autonomous Region, Liaoning Province, and Heilongjiang Province of China. From an integrated risk management perspective, and accounting for both the technological attributes and drought-resistant function of WSIT, this paper examines the combined effects of risk perception and risk attitude on farmers' adoption decisions. Risk perception is categorized into technological risk perception and drought risk perception. Furthermore, the moderating role of risk attitude is incorporated to investigate its interactive effect within the relationship between risk perception and WSIT adoption. The study thus offers a more systematic empirical and theoretical foundation for understanding farmers' technology adoption behavior under conditions of multiple risk sources.

This study makes three significant contributions to the existing literature. Firstly, in contrast to previous single-dimensional perspectives, we construct a novel theoretical framework, "The Farmer's Decision Model for Water-Saving Irrigation Technology Adoption Considering Risk Trade-offs". This framework posits that farmers' decision-making process in adopting WSIT, which have both "risk" and "instrument" attributes, is essentially a systematic risk-balancing process based on dual risk perception. It starts when farmers simultaneously assess the "instrumental risk" (the drought risk that the WSIT aims to address) and the "endogenous risk" (the new risks that may arise from adopting the technology itself). Based on this, farmers will integrate and calculate these two types of risks psychologically, forming the "perceived net risk benefit" (the expected value of avoiding drought losses minus the expected cost of the technical risk). When the perceived net risk benefit exceeds the individualized psychological threshold influenced by resources, society, and policies, adoption behavior occurs.

Secondly, different from previous single-dimensional studies, this paper integrates farmers' risk perception and risk attitude within a unified analytical framework to systematically examine their joint influence on the adoption of WSIT. By scientifically measuring risk perception through a risk matrix and designing a context-adapted lottery experiment based on the realities of Chinese agriculture, this study uses the multiple price list (MPL) method to accurately elicit farmers' risk attitudes. This approach provides comprehensive and scientifically rigorous empirical evidence for understanding WSIT adoption decisions.

Thirdly, by constructing a moderating effect model, this paper empirically tests for the first time the role of risk attitude as a moderator in the relationship between risk perception and WSIT adoption. It offers an in-depth analysis of how risk preferences amplify or attenuate the impact of risk perception on farmers' decision-making. This mechanistic investigation not only enhances theoretical understanding but also provides a critical foundation for the design of targeted policy interventions.

2 Theoretical basis and research hypothesis

Drawing on the theoretical framework of Prospect Theory, this study emphasizes that individual decision-making is influenced more strongly by subjective risk perceptions than by objective probabilities. Risk perception refers to farmers' cognition of the potential negative impact of agricultural risks on agricultural production and agricultural income (Ullah et al., 2017), including the possibility of agricultural risks and the size of negative impacts, which is widely used in farmers' risk decision-making framework (van Winsen et al., 2016; Fahad et al., 2018). Compared with actual risk occurrence, farmers' agricultural production decisions are more strongly influenced by their risk perception (Wauters et al., 2014). This leads to variations in production decisions based on differing risk perceptions (Alam and Guttormsen, 2019). WSIT is not only an agricultural innovation but also a critical tool for mitigating climate-related risks. Consequently, farmers' adoption decisions are shaped by two principal dimensions of perceived risk: "technology risk perception," stemming from novelty and uncertainty surrounding the technology itself, and encompassing apprehensions about potential yield reduction or income loss upon adopting WSIT; and "drought risk perception," originating from external environmental threats and farmers' subjective evaluations of the escalating frequency and potential detriment associated with extreme drought events. This study incorporates both types of risk perception into a theoretical analytical framework, aiming to examine the trade-off mechanism between technological and drought risks in farmers' decision-making. The following hypotheses are proposed:

H1: The higher the level of technical risk perception of farmers, the less willing they are to adopt WSIT.
H2: The higher the farmers' perception level of drought risk is, the more willing they are to adopt WSIT.

Risk attitude refers to farmers' willingness to take risks (Wauters et al., 2014). Under the framework of expected utility theory, risk attitude is measured by the curvature of the utility function. $u''(w)$ is an indicator for measuring the curvature of the utility function (Olarinde et al., 2007), where u represents utility and w represents the initial wealth of farmers. However, it will change with the positive monotonic transformation of the utility function. To eliminate the influence of this transformation, an indicator $u''(w)/u'(w)$ can be used. The relative risk aversion function is $R(w) = -u''(w)/u'(w)$, where $R(w)$ represents the degree of risk aversion. When $R(w) > 0$ it represents risk aversion; when $R(w) < 0$ it represents risk preference; when $R(w) = 0$, it represents risk neutrality. Although decision-making behaviors in different fields are related to risk perception, risk attitude is relatively stable. When farmers adopt new technologies, they will definitely consider maximizing profits and minimizing risks. Therefore, risk attitude is a key factor influencing farmers' adoption of new production technologies (Lybbert and Sumner, 2012). According to risk aversion theory, farmers with higher risk aversion may place greater emphasis on the technological risks associated with Water-Saving Irrigation Technology (WSIT), which can reduce their willingness to adopt it. However, if these farmers also perceive drought risks as more severe, the same risk-averse disposition may enhance their appraisal of WSIT's drought-mitigation functionality, thereby positively influencing adoption behavior. As agricultural technologies mature, overall technological risks tend to diminish, while climate uncertainty intensifies and drought risks become increasingly salient. Consequently, even when WSIT entails certain technological risks, highly risk-averse farmers—motivated by the desire to avoid potential drought-related losses—may still exhibit a greater propensity to adopt this technology. Based on this reasoning, the following hypotheses are proposed:

H3: Farmers with higher risk aversion will be more willing to adopt WSIT.

Farmers' differential risk perceptions are modulated by their underlying risk attitudes. When farmers exhibit a higher perception of technical risk, their concomitant risk aversion compels an overestimation of its severity. This amplified perception intensifies the negative influence of technical risk perception on WSIT adoption, thereby enacting a negative moderating role in the relationship between technical risk perception and WSIT adoption. Conversely, should farmers possess a heightened perception of drought risk, their inherent risk aversion prompts an overestimation of drought risk as well. This amplified perception of drought risk then potentiates its positive association with WSIT adoption, signifying that risk aversion positively moderates the relationship between drought risk perception and WSIT adoption. Based on these premises, this paper proposes the following hypothesis:

H4: Risk attitude negatively moderates the effect of technology risk perception on farmers' adoption of WSIT.
H5: Risk attitude positively moderates drought risk perception, influencing household adoption of WSIT.

3 Variable selection and model setting

The per capita water resources in China are only one-fourth of the world average (Wang et al., 2020). With the remarkable overall economic development in China and the high water-consumption trend in the manufacturing industry, the contradiction between water supply and demand will be further intensified. In June 2024, the Ministry of Water Resources released the "China Water Resources Bulletin 2023". The bulletin indicates that in 2023, the total national water consumption was 590.65 billion cubic meters. Among them, agricultural water consumption was 367.24 billion

m^3, accounting for 62.2% of the total water consumption. However, the effective utilization coefficient of farmland irrigation water in China is only 0.6, still significantly lower than the average level of 0.7–0.8 in developed countries (Shi et al., 2022; Zhang et al., 2021), which further intensifies the contradiction between water supply and demand in agricultural production. Therefore, adequate measures are urgently needed to improve the utilization rate of agricultural water resources in China. WSIT is not only one of the main tools for conserving agricultural water, but it can also withstand the increasingly extreme drought conditions. Therefore, promoting WSIT is an inevitable choice to address the contradiction between water supply and demand, thereby promoting the sustainable development of agriculture.

The selection of these three provinces (autonomous regions) as the survey area is mainly based on the following reasons: First, these three provinces (autonomous regions) are the central corn-growing provinces (autonomous regions) in China. In 2018, the total corn output of these three provinces (autonomous regions) accounted for 32.45% of the national total output, and during the period from 2008 to 2018, the total corn output of these three provinces (autonomous regions) accounted for more than 25% of the national total output, playing an essential role in China's corn food security. Second, the average total water resources volume of these three provinces (autonomous regions) is only approximately 154.1 billion cubic meters, accounting for 5.38% of the national average total water resources volume. Between 2012 and 2014, the average area affected by drought in these three provinces (autonomous regions) reached 446.7 thousand hectares, accounting for 42.19% of the national average area affected by drought. Third, the farmers in the survey area mainly rely on agriculture for their livelihood. These three provinces (autonomous regions) had an average total area of crop sowing of approximately 27,611 thousand hectares from 2014 to 2018, accounting for 16.61% of the national average total area of crop sowing. 51.32% of the farmers' agricultural income accounted for more than 65% of their total household income. Facing increasingly frequent extreme droughts, farmers urgently need to take proactive measures to cope with these events.

In conclusion, agricultural production in Heilongjiang Province, Liaoning Province, and the Inner Mongolia Autonomous Region holds a crucial position in China's overall agricultural production. However, their agricultural development is severely threatened by water shortage and frequent droughts. They urgently need to promote WSIT and improve the adoption efficiency of farmers for WSIT. Choosing these three provinces can provide theoretical and practical references for promoting WSIT in other regions.

This study adopts the method of random sampling. The research team first selected Harbin City, Shenyang City, and Chifeng City in Heilongjiang Province, Liaoning Province, and Inner Mongolia Autonomous Region as the survey areas, and then selected Shuangcheng District in Harbin City, Faku County in Shenyang City, and Aohan Qi in Chifeng City as the sample counties (cities). Subsequently, two urban districts, Lianxing Town, Dongguan Town and Qingling Township in Shuangcheng District, Woniushi Township in Faku County, and Changsheng Town and Mutouyingzi Township in Aohan Banner were selected as sample towns. Then, 1 to 5 administrative villages were randomly selected in each sample town, and 30 to 50 households were sampled from each administrative village for investigation. The respondents were household heads or members with knowledge of household production and operation who understood and were familiar with the survey content. The survey content mainly includes respondents' individual and household characteristics, basic agricultural production conditions, farmers' adoption of WSIT, agricultural risks, and farmers' adoption of risk management tools.

The survey was conducted through one-on-one household interviews. The investigators, all master's and doctoral candidates, received professional training before the survey and understood the purpose of setting each question in detail. In addition, to ensure the authenticity of the information, improve the farmers' cooperation, and reduce their vigilance, the investigators first identified themselves to the farmers before the survey, indicating that the questionnaire was only used for scientific research and paid each respondent a subsidy of 20 yuan for working. The survey collected data from 474 farmers, with 469 valid questionnaires retained after eliminating invalid responses, yielding an effective response rate of 98.95%.

3.1 Variable selection

(1) Explained variable. The variable explained in this study is the adoption of WSIT, which is based on asking the surveyed farm households whether they adopted WSIT. It is defined as 1 if the farmer has adopted WSIT and 0 if the farmer has not adopted WSIT.
(2) Key explanatory variables. The key explanatory variables in this study include technological risk perception, drought risk perception, and risk attitude. Among them, technical risk perception is obtained through the risk matrix; that is, the surveyed farmers were asked four questions: "Do you think the adoption of WSIT will lead to a decline in yield," "How much do you think the adoption of WSIT will lead to a decline in yield," "Do you think the adoption of WSIT will lead to a decline in quality," and "how much do you think the adoption of WSIT will lead to a decline in quality." The total risk perception coefficient is obtained by adding the average value of yield decline and quality decline. A risk perception coefficient greater than or equal to 6 is classified as high-risk perception and is assigned a value of 2. In cases where farmers have not adopted WSIT or lack sufficient understanding of it, they may be unable to assess the associated technical risks clearly. Due to this uncertainty in risk perception where farmers might perceive the technology as either high or low risk-the perception is categorized as indeterminate and assigned a value of 1. A risk perception coefficient below 6 is classified as low-risk perception and is assigned a value of 0.

The measurement of drought risk is also obtained through the risk matrix; The risk matrix is shown in Figure 1. That is, the surveyed farmers are asked, "How often do you think the drought risk occurs?" and "How severe do you think the drought risk occurs?" and the drought risk perception coefficient of farmers is obtained by adding the two. Because farmers understand drought risk and can make judgments based on their perception, the

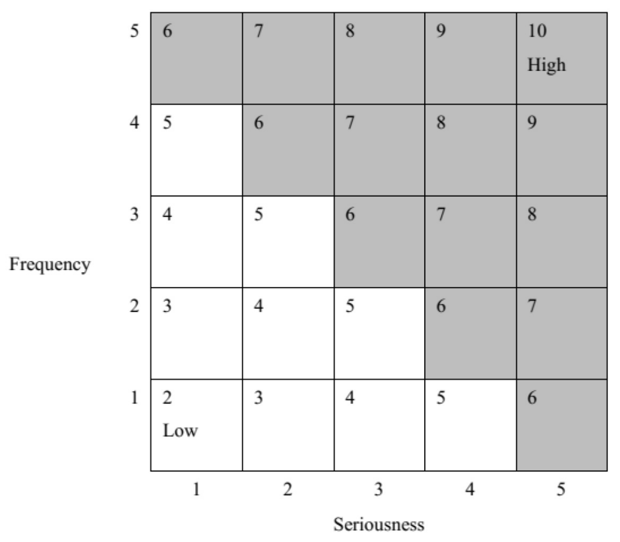

FIGURE 1
Risk matrix.

TABLE 1 Risk attitude measurement scale.

Number	Lottery A	Lottery B
1	A 10% chance is 1,600 yuan, and a 90% chance is 1,200 yuan	A 10% chance is 3,000 yuan, and a 90% chance is 80 yuan
2	A 20% chance is 1,600 yuan, and an 80% chance is 1,200 yuan	A 20% chance is 3,000 yuan, and an 80% chance is 80 yuan
3	A 30% chance is 1,600 yuan, and a 70% chance is 1,200 yuan	A 30% chance is 3,000 yuan, and a 70% chance is 80 yuan
4	A 40% chance is 1,600 yuan, and a 60% chance is 1,200 yuan	A 40% chance is 3,000 yuan, and a 60% chance is 80 yuan
5	A 50% chance is 1,600 yuan, and a 50% chance is 1,200 yuan	A 50% chance is 3,000 yuan, and a 50% chance is 80 yuan
6	A 60% chance is 1,600 yuan, and a 40% chance is 1,200 yuan	A 60% chance is 3,000 yuan, and a 40% chance is 80 yuan
7	A 70% chance is 1,600 yuan, and a 30% chance is 1,200 yuan	A 70% chance is 3,000 yuan, and a 30% chance is 80 yuan
8	An 80% chance is 1,600 yuan, and a 20% chance is 1,200 yuan	An 80% chance is 3,000 yuan, and a 20% chance is 80 yuan
9	A 90% chance is 1,600 yuan, and a 10% chance is 1,200 yuan	A 90% chance is 3,000 yuan, and a 10% chance is 80 yuan
10	A 100% chance is 1,600 yuan, and a 0% chance is 1,200 yuan	A 100% chance is 3,000 yuan, and a 0% chance is 80 yuan

drought risk perception coefficient is directly used to measure the drought risk perception of farmers.

Attitude to risk. Multiple price lists (MPLs) effectively test risk attitudes (Hellerstein et al., 2013; Lucas and Pabuayon, 2011). This method requires farmers to choose the lottery that meets their expectations from 10 pairs of lotteries (each of which contains Lottery A and Lottery B), that is, lottery A or Lottery B. Referring to the setting of the original lottery value in previous studies and the actual situation in rural China, the research team set the initial value of the lottery at 1,600 or 1,200 yuan (Lottery A) and 3,000 or 80 yuan (Lottery B). In each of the 10 scenarios, the probability varies by 10%, and the expected payoff also changes. See Table 1 for the design of the 10 pairs of lotteries. Compared with Lottery B, the return of Lottery A fluctuates less (only 400 yuan), which is a safe option. In decision situations 1–4, the expected payoff of Lottery A exceeds that of Lottery B. In decision situations 5–10, the expected payoff of Lottery B exceeds that of Lottery A.

Risk attitudes were measured by the number of safety options selected by the farmers. The number of safe options indicates the frequency with which farmers choose lottery A. The higher the frequency with which farmers choose Lottery A, the higher the degree of risk aversion (Holt and Laury, 2002). Zero to three safety options represent risk preference, 4 safety options represent risk neutrality, and 5–9 safety options represent risk aversion (Holt and Laury, 2002). The risk measurement results of farmers are shown in Table 2.

(3) Control variables. According to the existing research, this paper selects the gender of the respondent, the years of education, the years of farming, the total land area, land quality, agricultural income, agricultural expenditure, total population, labor force, and income stability of the respondent's family as control variables. The variable names and their meanings are shown in Table 3.

TABLE 2 Measurement results of farmers' risk attitude.

Number	The number of security options	Risk attitude
1	0	Extreme risk appetite
2	1	High-risk appetite
3	2	Very risk appetite
4	3	General risk appetite
5	4	Risk neutral
6	5	Mild risk aversion
7	6	General risk aversion
8	7	Very risk averse
9	8	High-risk aversion
10	9	Perfect risk aversion

3.2 Model setting

This study investigates how farmers' risk perceptions (technological and drought-related) and risk attitudes influence their adoption decisions regarding WSIT. Since the explained variable in this paper is the adoption of WSIT, which is 0 and 1 variable, this paper adopts the Logit model for empirical analysis.

$$P_i = F(Y) = F(\alpha_0 + \alpha_1 x_1 + \ldots + \alpha_i x_i + \theta_i) = \frac{1}{1 + \exp[-(\alpha_0 + \alpha_1 x_1 + \ldots + \alpha_i x_i + \theta_i)]} \quad (1)$$

This Model can be converted to:

$$ln \frac{P_i}{1 - P_i} = y_i = \alpha_0 + \alpha_1 RP + \alpha_2 RA \ldots + \alpha_i x_i + \theta_i \quad (2)$$

TABLE 3 Variable names and their meanings.

Variable name	Variable meaning	Mean	Std. dev.	Min	Max
Adoption of water-saving irrigation technology	The adoption of water-saving irrigation technology by farmers is 1 for yes and 0 for no.	0.473	0.500	0	1
Technical risk perception	The risk perception of farmers regarding adopting water-saving irrigation technology, high-risk perception of technology = 2, unclear = 1, low-risk perception of technology = 0.	0.552	0.527	0	2
Drought risk perception	The respondents' perception of drought risks	8.795	1.596	2	10
Attitude to risk	The number of safe options.	5.785	2.762	0	9
Gender	The gender of farmers is male = 1, female = 0.	0.620	0.486	0	1
Years of education	The number of years the respondents have spent in school	6.792	2.688	0	18
Ln_Years of farming	The logarithm of the total years of agricultural production experience of the interviewees	3.379	0.429	1.099	4.094
Ln_Total land area	The logarithm of the total land area of the interviewed family	3.204	0.856	0.693	5.999
Quality of land	The quality of the cultivated land of the respondents' families. 1 = poor; 2 = relatively poor; 3 = average; 4 = relatively good; 5 = good.	3.507	0.767	1	5
Income from agriculture	Agricultural income (yuan)	3.296	3.810	0.15	35
Agricultural expenditure	Agricultural expenditure (yuan)	2.166	2.968	0.1	25
Total population	The total number of family members (people)	3.932	1.405	1	8
Labor force	The number of family laborers (people)	2.554	0.991	0	7
Stability of income	Is the income of your family stable? 1 = very unstable, 2 = relatively unstable; 3 = average; 4 = relatively stable; 5 = very stable	3.178	1.131	1	5
Peer effect	The surrounding farmers have adopted water-saving irrigation techniques, and I am willing to do so as well. 0 = not adopted, 1 = disagree, 2 = not too agree, 3 = general, 4 = relatively agree, 5 = very agree	2.791	1.945	0	5
The effectiveness of technical training	Through technical training, I can master water-saving irrigation techniques very well. 1 = disagree, 2 = not too agree, 3 = general, 4 = relatively agree, 5 = very agree	3.829	1.096	1	5
Regional fixed effect	The survey area is Heilongjiang = 1; otherwise = 0	0.205	0.404	0	1

In Model 2, P_i represents the probability that farmers adopt WSIT. y_i represents whether farmers adopt WSIT, and RP represents technology risk perception and drought risk perception; RA stands for risk attitude; $x_i$represents the control variable; αdenotes the intercept term of the regression equation, and θ_i denotes the random disturbance term.

$$\ln \frac{P_i}{1-P_i} = y = \alpha_0 + \alpha_1 RP + \alpha_2 RA + \alpha_2 RP{*}PA \ldots + \alpha_i x_i + \theta_i \quad (3)$$

This study further introduces interaction terms between risk perception and risk attitude into Model 2 to create Model 3. Specifically, we include interactions between (a) technological risk perception and risk attitude, and (b) drought risk perception and risk attitude, to examine how risk attitude moderates the effect of risk perception on farmers' WSIT adoption. In Model 3, RP^*PA represents the interaction term of risk perception and risk attitude.

4 Empirical results and analysis

4.1 Descriptive statistical analysis

Table 4 summarizes farmers' adoption of WSIT alongside their associated risk perceptions and attitudes. The data indicate that 47.33% of farmers have adopted WSIT, suggesting a relatively low current adoption rate and highlighting the need for enhanced promotion efforts. Regarding technological risk perception, 52.24% of farmers report an unclear understanding of the technical risks involved in WSIT adoption, while 1.49% perceive these risks as high. This suggests that a majority of farmers lack awareness of potential technical risks, mainly due to the non-adoption of these risks. In contexts of uncertainty, individuals often exhibit resistance to change, a tendency reflected in the finding that 68.23% of farmers are risk-averse. This prevalent risk aversion may further inhibit WSIT adoption. Conversely, 95.52% of farmers demonstrate a high perception of drought risk, indicating that the frequency and severity of extreme drought events have significantly raised farmers' concerns. This elevated risk perception is likely to motivate adoption of WSIT as an adaptive response. The fact that 68.23% of farmers are risk-averse—compared to only 19.19% who are risk-seeking—further underscores the conservative risk attitude prevailing among the majority, who prefer to avoid excessive agricultural risks.

4.2 The impact of risk perception and risk attitude on farmers' adoption of WSIT

This paper utilizes Stata 15 and the binary Logit model to analyze the impact of risk perception and risk attitude on farmers'

TABLE 4 Descriptive statistical results.

The adoption of water-saving irrigation technology	Frequency	Proportion (%)	Perception of drought risk	Frequency	Proportion (%)
No	247	52.67	Low	21	4.48
Yes	222	47.33	High	448	95.52
Perception of technical risks			Risk attitude		
Low	217	46.27	Risk appetite	90	19.19
Not clear	245	52.24	Risk-neutral	59	12.58
High	7	1.49	Risk aversion	320	68.23

adoption of WSIT, incorporating technical risk perception and control variables, drought risk perception and control variables, risk attitude, and control variables into the Model, respectively, and examining their marginal effects. The results are shown in Table 5.

As shown in Table 5, technological risk perception exerts a statistically significant negative effect on farmers' WSIT adoption, thus supporting Hypothesis H1. The results indicate that farmers are more reluctant to adopt WSIT when they perceive it as being higher or cannot determine its technical risk. At the same time, according to the results of marginal analysis, for every standard deviation increase in the uncertainty and risk of farmers' perception of WSIT risk, the probability of farmers adopting WSIT will decrease by 24.7%. Drought risk perception has a significant impact on farmers' adoption of WSIT at a 1% statistical level, verifying Hypothesis H2. The results show that increased drought risk probability significantly raises the likelihood of WSIT adoption. Marginal effect analysis indicates that a one standard deviation increase in farmers' drought risk perception is associated with a 3.6 percentage point increase in the probability of WSIT adoption. Risk aversion attitude significantly positively affects household adoption of WSIT at the 1% statistical level. The result indicates that the more averse the farmers are to drought risk, the more willing they are to adopt WSIT. Marginal effect analysis reveals that a one-standard-deviation increase in farmers' risk aversion is associated with a 2.6 percentage-point increase in the probability of WSIT adoption.

4.3 Robustness test

This study examined the robustness of the research results by changing the econometric model and adjusting the sample size. The results are shown in Table 6.

(1) Changing the econometric Model.

To test the robustness of the results in this study, a Probit model was employed for further robustness testing. The binary Probit model is a statistical method used to handle binary classification problems, which is applicable when the dependent variable is binary (such as 0/1 or yes/no). Its core is to map the linear combination of independent variables to probability values through the cumulative distribution function (CDF) of the standard normal distribution. The WSIT adopted in this study is a binary variable; therefore, this study modified the econometric Model for robustness testing. The results are shown in the first to third columns of Table 6.

(2) Adjusting the sample.

Since land plots with an area less than 1 acre are not suitable for WSIT, in order to make the research sample more in line with the actual situation, this study removed farmers with land plots smaller than 1 acre and explored the robustness of the influence of risk perception and risk attitude on the adoption of water-saving irrigation technology. The results are shown in the fourth to fifth columns of Table 6.

Table 6 presents the robustness test results examining the effects of risk perception and risk attitude on farmers' WSIT adoption. Whether through Probit model regression or removing farmers with each plot area less than 1 mu, technology risk perception still negatively impacts adopting WSIT at the statistical level of 1%. In contrast, both drought risk perception and risk attitude demonstrate statistically significant effects on WSIT adoption at the 1% level. These findings are consistent with the earlier reported regression results, confirming that both risk perception and risk attitude are robust determinants of farmers' WSIT adoption.

4.4 The impact of risk perception and risk attitude on WSIT adoption across farm sizes

Landholding scale significantly influences farmers' agricultural input investments and the contribution of agricultural production to household income. Specifically, large-scale farmers derive a greater proportion of their household income from agriculture and consequently allocate more resources to agricultural production costs. Considering this heterogeneity, this paper investigates the differential technical risk perception, drought risk perception, and risk attitudes among small- and large-scale farmers, and how these factors impact their adoption of WSIT. Farmers were categorized as small-scale or large-scale based on whether their average landholding was below or above the total land area. Table 7 presents the results of the impact of risk perception and risk attitude on WSIT adoption across these farm size categories.

Table 7 reveals that technological risk perception exerts statistically significant negative effects on WSIT adoption at the 1% level for both farm scales, with coefficients of −5.237 (small-scale) and −7.283 (large-scale), respectively. Both large-scale and small-scale farmers exhibit heightened sensitivity to technological

TABLE 5 Regression results of the impact of risk perception and risk attitude on the adoption of water-saving irrigation technology.

Variable name	Regression result	Marginal effect	regression result	Marginal effect	regression result	Marginal effect
Technical risk perception	−5.382***	−0.247***				
	(0.531)	(0.024)				
Drought risk perception			0.250***	0.036***		
			(0.090)	(0.013)		
Attitude to risk					0.181***	0.026***
					(0.052)	(0.007)
Gender	−0.131	−0.006	0.225	0.033	0.304	0.043
	(0.493)	(0.023)	(0.267)	(0.039)	(0.270)	(0.038)
Years of education	−0.141	−0.006	−0.195***	−0.028***	−0.176***	−0.025***
	(0.094)	(0.004)	(0.052)	(0.007)	(0.052)	(0.007)
ln_Years of farming	0.472	0.022	0.376	0.054	0.382	0.054
	(0.538)	(0.025)	(0.304)	(0.044)	(0.302)	(0.043)
ln_Total land area	−0.211	−0.010	−0.186	−0.027	−0.222	−0.032
	(0.289)	(0.013)	(0.147)	(0.021)	(0.148)	(0.021)
Quality of land	−0.095	−0.004	0.063	0.009	0.029	0.004
	(0.309)	(0.014)	(0.180)	(0.026)	(0.179)	(0.025)
Income from agriculture	0.044	0.002	−0.025	−0.004	−0.024	−0.003
	(0.124)	(0.006)	(0.069)	(0.010)	(0.070)	(0.010)
Agricultural expenditure	−0.148	−0.007	0.103	0.015	0.089	0.013
	(0.146)	(0.007)	(0.088)	(0.013)	(0.086)	(0.012)
Total population	0.357*	0.016*	0.061	0.009	0.062	0.009
	(0.188)	(0.009)	(0.106)	(0.015)	(0.110)	(0.016)
Labor force	−0.633**	−0.029**	−0.308**	−0.045**	−0.244	−0.035
	(0.279)	(0.013)	(0.154)	(0.022)	(0.157)	(0.022)
Stability of income	−0.284	−0.013	−0.106	−0.015	−0.156	−0.022
	(0.217)	(0.010)	(0.124)	(0.018)	(0.124)	(0.018)
Peer effect	0.452***	0.021***	0.430***	0.062***	0.425***	0.061***
	(0.132)	(0.006)	(0.073)	(0.009)	(0.072)	(0.009)
The effectiveness of technical training	0.189	0.009	0.342***	0.050***	0.454***	0.065***
	(0.226)	(0.010)	(0.129)	(0.018)	(0.133)	(0.018)
Regional fixed effect	−1.977***	−0.091***	−3.999***	−0.580***	−4.010***	−0.572***
	(0.714)	(0.034)	(0.526)	(0.057)	(0.536)	(0.058)
_cons	3.162		−2.988*		−2.214	
	(2.677)		(1.708)		(1.560)	
Log likelihood	−74.124		−188.289		−185.935	
LR chi2(11)	440.248		211.916		216.625	
Prob > chi2	0.000		0.000		0.000	
Pseudo R2	0.748		0.360		0.368	

***, **, and * represent that the estimated results are significant at 1%, 5%, and 10%, respectively.
Values in parentheses are regression standard errors.

TABLE 6 Robustness test.

Variable name	Probit model			Each land area is less than 1 mu of farmers		
Technical risk perception	−2.476***			−5.305***		
	(0.203)			(0.531)		
Drought risk perception		0.127**			0.225**	
		(0.051)			(0.091)	
Attitude to risk			0.100***			0.182***
			(0.029)			(0.053)
Gender	−0.042	0.148	0.188	−0.131	0.225	0.305
	(0.221)	(0.156)	(0.157)	(0.493)	(0.271)	(0.275)
Years of education	−0.065	−0.111***	−0.105***	−0.143	−0.199***	−0.178***
	(0.043)	(0.030)	(0.030)	(0.094)	(0.053)	(0.054)
ln_Years of farming	0.136	0.236	0.265	0.484	0.405	0.410
	(0.227)	(0.173)	(0.174)	(0.536)	(0.306)	(0.305)
ln_Total land area	−0.115	−0.103	−0.119	−0.190	−0.162	−0.192
	(0.125)	(0.086)	(0.086)	(0.289)	(0.149)	(0.150)
Quality of land	−0.040	0.025	0.013	−0.089	0.086	0.062
	(0.138)	(0.101)	(0.101)	(0.310)	(0.181)	(0.182)
Income from agriculture	0.018	−0.013	−0.014	0.046	−0.020	−0.021
	(0.056)	(0.038)	(0.039)	(0.124)	(0.070)	(0.071)
Agricultural expenditure	−0.069	0.053	0.048	−0.142	0.108	0.096
	(0.067)	(0.048)	(0.048)	(0.145)	(0.089)	(0.086)
Total population	0.224***	0.051	0.047	0.362*	0.077	0.082
	(0.086)	(0.060)	(0.061)	(0.188)	(0.107)	(0.111)
Labor force	−0.377***	−0.190**	−0.148	−0.635**	−0.321**	−0.262*
	(0.126)	(0.089)	(0.091)	(0.277)	(0.155)	(0.159)
Stability of income	−0.147	−0.067	−0.088	−0.283	−0.110	−0.154
	(0.098)	(0.071)	(0.070)	(0.217)	(0.125)	(0.126)
Peer effect	0.258***	0.249***	0.247***	0.457***	0.440***	0.437***
	(0.060)	(0.041)	(0.041)	(0.132)	(0.074)	(0.074)
The effectiveness of technical training	0.126	0.188**	0.244***	0.193	0.345***	0.455***
	(0.104)	(0.074)	(0.075)	(0.226)	(0.130)	(0.135)
Regional fixed effect	−1.075***	−2.170***	−2.188***	−1.967***	−3.962***	−3.971***
	(0.296)	(0.249)	(0.255)	(0.711)	(0.531)	(0.543)
_cons	1.626	−1.584*	−1.346	2.912	−3.144*	−2.676*
	(1.178)	(0.961)	(0.886)	(2.703)	(1.737)	(1.601)
Log likelihood	−86.402	−189.743	−186.979	−73.467	−183.025	−180.107
LR chi2(11)	415.692	209.009	214.537	424.132	205.015	210.852
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.706	0.355	0.365	0.743	0.359	0.369

***, **, and * represent that the estimated results are significant at 1%, 5%, and 10%, respectively.
Values in parentheses are regression standard errors.

risks when adopting new agricultural technologies. Elevated technological risk perception significantly impedes the adoption of WSIT, while insufficient risk awareness creates similar adoption barriers. Notably, large-scale farmers demonstrate significantly higher technological risk perception coefficients than small-scale farmers. This suggests that large-scale operations, while potentially

TABLE 7 Regression results of adoption of water-saving irrigation technologies by farmers of different scales.

Variable name	Small scale	Large scale	Small scale	Large scale	Small scale	Large scale
Technical risk perception	−5.237***	−7.283***				
	(0.624)	(1.756)				
Drought risk perception			0.307***	0.173		
			(0.110)	(0.219)		
Attitude to risk					0.150**	0.300**
					(0.060)	(0.145)
Gender	−0.179	0.213	0.241	−0.089	0.260	0.239
	(0.558)	(1.497)	(0.310)	(0.695)	(0.308)	(0.721)
Years of education	−0.204*	0.105	−0.222***	−0.031	−0.207***	−0.000
	(0.112)	(0.322)	(0.059)	(0.144)	(0.060)	(0.150)
ln_Years of farming	0.910	−0.765	0.721**	−0.129	0.645*	0.261
	(0.613)	(1.704)	(0.363)	(0.733)	(0.356)	(0.770)
ln_Total land area	−0.147	−0.496	−0.146	−0.570	−0.201	−0.588
	(0.304)	(1.139)	(0.171)	(0.392)	(0.171)	(0.398)
Quality of land	−0.005	0.035	0.264	−0.938*	0.200	−0.958*
	(0.346)	(1.119)	(0.210)	(0.508)	(0.206)	(0.525)
Income from agriculture	−0.400	0.127	−0.444***	0.212*	−0.387***	0.221*
	(0.266)	(0.226)	(0.153)	(0.120)	(0.146)	(0.122)
Agricultural expenditure	−0.255	−0.161	0.256	−0.063	0.284*	−0.067
	(0.281)	(0.274)	(0.174)	(0.124)	(0.171)	(0.119)
Total population	0.529**	0.358	0.121	−0.084	0.132	−0.120
	(0.235)	(0.521)	(0.125)	(0.247)	(0.129)	(0.248)
Labor force	−0.731**	−0.203	−0.335*	0.083	−0.281	0.195
	(0.334)	(0.798)	(0.184)	(0.372)	(0.186)	(0.405)
Stability of income	−0.380	−0.312	−0.156	−0.111	−0.215	−0.129
	(0.261)	(0.593)	(0.153)	(0.289)	(0.152)	(0.293)
Peer effect	0.529***	0.507	0.486***	0.417**	0.454***	0.513***
	(0.156)	(0.431)	(0.089)	(0.187)	(0.086)	(0.198)
The effectiveness of technical training	0.279	−0.076	0.329**	0.874**	0.426***	1.004**
	(0.247)	(0.855)	(0.145)	(0.398)	(0.147)	(0.432)
Regional fixed effect	−2.713***	−1.327	−3.965***	−5.456***	−3.817***	−6.033***
	(0.912)	(1.788)	(0.683)	(1.170)	(0.682)	(1.341)
_cons	2.037	6.367	−4.779**	0.340	−2.806	−2.419
	(2.921)	(9.593)	(2.082)	(3.900)	(1.803)	(4.239)
Log likelihood	−56.326	−11.921	−137.390	−38.944	−138.403	−36.802
LR chi2(11)	309.772	142.214	147.642	88.167	145.617	92.451
Prob > chi2	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R2	0.733	0.856	0.350	0.531	0.345	0.557

***, **, and * represent that the estimated results are significant at 1%, 5%, and 10%, respectively.
Values in parentheses are regression standard errors.

benefiting more from technology adoption, face proportionally higher adoption costs and consequently exhibit greater risk sensitivity in their technology evaluation processes.

Regression results reveal differential significance levels: drought risk perception increases the WSIT adoption probability by 0.307 units (1% significance) for small-scale farmers. It can be concluded that small-scale farmers will actively adopt WSIT due to the high level of drought risk perception, and the impact of drought risk perception on small-scale farmers is more sensitive than large-scale farms.

Regression results indicate that risk attitude significantly increases the probability of WSIT adoption: by 0.150 units (5% level) for small-scale operations and 0.300 units (5% level) for large-scale farms, suggesting more substantial marginal effects for larger operations. Risk-averse farmers exhibit stronger adoption intentions, likely due to WSIT's perceived risk mitigation benefits against agricultural uncertainties. Consistent adoption patterns reflect farmers' shared understanding of WSIT's capacity to enhance drought resilience in agricultural production.

4.5 Risk attitude as a moderator between risk perception and WSIT adoption

To examine risk attitude's moderating role in the risk perception and WSIT adoption relationship, we estimate two regression models: (1) technological risk perception × risk attitude with controls, and (2) drought risk perception × risk attitude with controls. The research results are shown in Table 8. According to the regression results in Table 8, when risk perception and risk attitude are modeled simultaneously, both risk perception and risk attitude significantly impact farmers' WSIT. Models 3 and 4 extend the baseline specifications by introducing respective interaction terms between risk perception dimensions (technological/drought) and risk attitude.

According to Regression (3) results, the interaction term between technical risk perception and risk attitude significantly positively impacts farmers' adoption of WSIT at the statistical level of 1%. Risk aversion will mitigate the negative impact of technical risk perception on farmers' adoption of WSIT; therefore, hypothesis H4 is not verified. The lack of support for Hypothesis 4 may be attributed to the dual nature of Water-Saving Irrigation Technology (WSIT) in farmers' decision-making: it represents both an innovative technology carrying inherent uncertainties and a critical instrument for mitigating drought risks. Although risk-averse farmers generally exhibit caution toward new technologies, intensified climate change and increased drought frequency may lead their concerns regarding drought risks to outweigh their apprehensions about technological risks. According to Protection Motivation Theory, when individuals perceive a severe environmental threat and believe in their ability to implement effective countermeasures, they may still adopt risk-reducing behaviors—even if those actions entail certain risks—to avoid greater losses. Thus, even when perceiving substantial technological risks, highly risk-averse farmers may be driven by the motivation to prevent drought-induced losses and may still tend to adopt WSIT. This behavioral response suggests an inverse moderating effect of risk attitude: a higher degree of risk aversion may attenuate, rather than amplify, the negative influence of technological risk perception on adoption behavior.

According to Regression (4) results, the interaction term between drought risk perception and risk attitude has significantly negative impacts effect on the impact of drought risk on farmers' adoption of WSIT, so Hypothesis H5 is not verified. Theoretically, this might stem from the complexity of the cognitive-attitudinal-behavioral path that farmers follow in making risk-technology decisions. Although the perception of drought risk generally promotes the adoption of WSIT, the risk attitude fails to play the expected reinforcing role in this relationship. One possible explanation is that the technical risks brought by WSIT itself (such as system failures, high adaptation costs, unfamiliarity with operation, etc.) are all taken into consideration in farmers' decisions, forming a "risk offset" mechanism. That is, for those farmers with a higher degree of risk aversion, although their perception of drought risk is stronger, their concerns about technical risks are also simultaneously activated, thus resulting in the fact that the promoting effect of drought risk perception on the adoption behavior does not further increase with the improvement of risk aversion degree. This result, to some extent, conforms to the explanation of the "Dual-Process Theory": emotional risk responses (such as fear of drought) and cognitive technical assessment (such as doubt about the reliability of WSIT) may both play a role in decision-making and partially offset each other's influence on the final behavior.

5 Discussions

The above empirical estimation results consistently indicate that risk perception and risk attitude play a significant role in farmers' adoption of WSIT. Here, we discuss the reasons for the above empirical results.

First, the adverse effect of technological risk perception aligns with perceived risk theory and is consistent with existing studies on the adoption of agricultural technology (Yang et al., 2025; Yu et al., 2024). Systemic risks associated with the promotion of new technologies can hinder their widespread adoption (Tzachor et al., 2022; Dai et al., 2015). Concerns regarding technical complexity, operational challenges, or equipment reliability may reduce farmers' willingness to adopt (Adla et al., 2024). Even when long-term benefits are evident, short-term perceptions of high maintenance costs or poor adaptability can inhibit adoption. This further reflects the role of information asymmetry: insufficient knowledge about actual benefits may amplify risk expectations and suppress adoption (Hong et al., 2024).

Second, the positive impact of drought risk perception can be understood through risk coping theory. Climate change represents a major agricultural threat, particularly in arid regions (Javed and Khan, 2019). When farmers perceive increased production uncertainty due to climate variability, their motivation to adopt adaptive technologies to stabilize income becomes stronger (Hansen et al., 2019). This result corroborates earlier findings that higher risk perception increases the likelihood of adopting new technologies to mitigate potential losses (Liu H. et al., 2025; Liu Y. et al., 2025; Li and Huang, 2023). As extreme weather events intensify, farmers are increasingly likely to employ risk management tools to reduce agricultural vulnerabilities and safeguard yields.

Third, the positive effect of risk aversion attitude reflects the logic of expected utility theory, wherein risk-averse individuals prefer specific outcomes over uncertain losses. This result suggests

10.3389/fsufs.2025.1633132

TABLE 8 Moderating effect of risk attitude on risk perception affecting water-saving irrigation technology adoption.

Variable name	Regression (1)	Regression (2)	Regression (3)	Regression (4)
Technical risk perception × risk attitude			1.787***	
			(0.464)	
Drought risk perception × risk attitude				−0.109**
				(0.044)
Technical risk perception	−5.619***		−18.892***	
	(0.586)		(3.988)	
Drought risk perception		0.283***		0.952***
		(0.092)		(0.289)
Attitude to risk	0.314***	0.199***	−0.132	1.222***
	(0.099)	(0.054)	(0.168)	(0.417)
Gender	−0.075	0.299	−0.139	0.246
	(0.518)	(0.274)	(0.592)	(0.277)
Years of education	−0.131	−0.176***	−0.095	−0.179***
	(0.096)	(0.053)	(0.106)	(0.053)
ln_Years of farming	0.600	0.379	0.964	0.429
	(0.543)	(0.310)	(0.642)	(0.317)
ln_Total land area	−0.292	−0.214	−0.383	−0.228
	(0.287)	(0.151)	(0.283)	(0.153)
Quality of land	−0.122	0.060	−0.340	0.012
	(0.333)	(0.182)	(0.413)	(0.185)
Income from agriculture	0.013	−0.046	0.005	−0.055
	(0.126)	(0.068)	(0.138)	(0.070)
Agricultural expenditure	−0.109	0.115	−0.087	0.138*
	(0.137)	(0.083)	(0.179)	(0.081)
Total population	0.358*	0.059	0.154	0.058
	(0.194)	(0.111)	(0.224)	(0.112)
Labor force	−0.584*	−0.257	−0.089	−0.250
	(0.303)	(0.160)	(0.336)	(0.163)
Stability of income	−0.222	−0.092	0.135	−0.082
	(0.216)	(0.127)	(0.246)	(0.127)
Peer effect	0.465***	0.437***	0.547***	0.441***
	(0.136)	(0.074)	(0.162)	(0.075)
The effectiveness of technical training	0.260	0.415***	0.092	0.455***
	(0.231)	(0.135)	(0.237)	(0.137)
Regional fixed effect	−1.765**	−3.969***	−2.354***	−4.129***
	(0.699)	(0.545)	(0.804)	(0.559)
_cons	0.636	−4.972***	1.830	−11.413***
	(2.765)	(1.842)	(3.220)	(3.238)
N	425	425	425	425
Log likelihood	−68.657	−181.058	−52.433	−177.753
LR chi2(11)	451.181	226.379	483.629	232.989
Prob > chi2	0.000	0.000	0.000	0.000
Pseudo R2	0.767	0.385	0.822	0.396

***, **, and * represent that the estimated results are significant at 1%, 5%, and 10%, respectively.
Values in parentheses are regression standard errors.

that farmers tend to adopt risk management tools—such as smart irrigation—to mitigate the severe consequences of agricultural risks (Wibowo et al., 2019; Hossain, 2025). Most farmers exhibit risk-averse tendencies (Farhan et al., 2022; Ahmad et al., 2019), and with increasing climate extremes, they become more sensitive to drought risks and more willing to take preventive measures—such as adopting water-saving technologies—to secure agricultural income. This behavioral pattern mirrors mechanisms observed in agricultural insurance adoption (Yang et al., 2025), where risk-averse individuals seek to reduce potential losses through preventive investments or risk-mitigating technologies.

Fourth, risk aversion attenuates the adverse effect of technological risk perception on adoption, encouraging farmers to implement WSIT despite technical uncertainties. As shown in Table 4, 95.52% of farmers exhibit a high perception of drought risk, which strengthens their motivation to act. According to protection motivation theory, when individuals perceive a threat as severe and believe they can respond effectively, they are more likely to adopt protective measures—even if those measures entail secondary risks. A risk compensation mechanism may also operate: when farmers perceive that adopting WSIT can effectively reduce drought risk (benefit), they become willing to bear certain technical risks (cost), resulting in a cognitive trade-off between multiple risk sources (Villacis et al., 2021). This result is consistent with the research of Bommier and Le Grand (2019), which shows that risk-averse farmers are more willing to adopt WSIT when the perception of drought risk is more pronounced, actively reducing the impact of drought risks.

6 Conclusion

This paper uses farmer survey data to analyze the adoption of WSIT. Specifically, this paper first analyzes farmers' evaluation of WSIT and its impact on their adoption behavior. Furthermore, the binary Logit model and moderating effect model were used to empirically analyze the impacts of risk perception and risk attitude on the adoption of WSIT by farmers, as key factors affecting agricultural risk management, and the differences in the impacts of risk perception and risk attitude among farmers with different characteristics. Finally, the moderating effect of risk attitude on the impact of risk perception on farmers' adoption of WSIT and the differences in the moderating effect of risk attitude among farmers with different characteristics are investigated. The main conclusions are as follows:

(1) Technology risk perception significantly negatively impacts farmers' adoption of WSIT. Conversely, farmers' perceptions of drought risk and risk attitudes positively and significantly influence WSIT adoption decisions. It can be seen that adopting WSIT can help farmers resist agricultural risks. Moreover, the above results remain unchanged after the Probit model is applied or the farmers with each land area less than 1 mu are deleted, indicating that the impact of farmers' risk perception and risk attitude on adopting WSIT is robust.

(2) The impact of risk perception and risk attitude of farmers with different characteristics on their adoption of WSIT showed that the technical risk perception of small-scale farmers and large-scale farmers had a significantly negative impact, and the impact coefficient on large-scale farmers was significantly higher than that on small-scale farmers. Drought risk perception has a significant positive impact on small-scale farmers. Risk attitude has a significant positive effect on both small-scale and large-scale farmers, with a higher coefficient for large-scale farmers compared to small-scale farmers.

(3) The interaction term between technical risk perception and risk preference indicates that risk preference has a significant positive impact on farmers' adoption of risk reduction tools, even though it negatively affects their perception of technical risks. This suggests that farmers' risk-averse attitude will weaken their perception of technical risks, prompting them to adopt WSIT more actively. The risk attitude exerts a negative moderating influence on farmers' behavior of adopting WSIT in response to drought risk perception. This implies that while both farmers' perception of drought risk and their risk-averse attitude can stimulate them to adopt WSIT, for those with an extremely positive risk attitude (i.e., those highly willing to take action), the promoting effect of risk perception will be attenuated.

On the practical front, this paper offers valuable perspectives for advancing WSIT, bolstering farmers' capabilities to mitigate drought risks, and fostering sustainable agricultural development.

To begin with, for farmers characterized by low-risk perception and a risk-averse mindset, it is imperative to deepen their comprehension of risk information, thus stimulating their enthusiasm for adopting WSIT. Concretely, relevant authorities can leverage historical data, such as the decline in grain production attributed to natural risks in prior years, to forecast future natural risks and expeditiously disseminate the predicted risk intelligence to farmers. It is recommended that local television stations initiate specialized agricultural risk management programs to broadcast the current year's abnormal temperature and precipitation patterns, along with their potential adverse impacts on agricultural production.

Secondly, for the same group of farmers with low-risk perception and risk aversion, enhancing the accuracy of their risk perception is crucial to augment their eagerness to adopt WSIT. Specifically, local agricultural departments can utilize mobile messaging services or WeChat public accounts to disseminate real-time weather updates and price fluctuations of agricultural products. Village committees can assign dedicated personnel to promptly post or forward natural and market risk information in WeChat groups and encourage farmers to study and share this information. Through such comprehensive and multi-tiered dissemination of agricultural risk information, the accuracy of farmers' risk perception can be effectively improved.

This paper focuses on exploring the impact of risk perception and risk attitude on farmers' adoption of WSIT from the perspective of risk reduction, and further examines the moderating effect of risk attitude, thereby enriching existing research. One limitation of this study is that we only focused on corn growers in three provinces in China. In future research, it is necessary to conduct further studies and include other crops and a larger sample size.

Data availability statement

Data are available from the corresponding author on reasonable request.

Author contributions

YS: Funding acquisition, Methodology, Software, Validation, Writing – original draft, Writing – review & editing, Conceptualization. YH: Conceptualization, Methodology, Software, Visualization, Writing – review & editing. YZ: Validation, Writing – original draft.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was supported by the General Project of Humanities and Social Sciences of the Ministry of Education (Project No. 24YJC790146), National Natural Science Foundation of China (Project No. 72403189), Hubei Provincial Department of Education Science and Technology Research Plan (Project No. Q20231502).

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Adla, S., Saponjic, A., Tyagi, A., Nagi, A., Pastore, P., Pande, S., et al. (2024). Steering agricultural interventions towards sustained irrigation adoption by farmers: socio-psychological analysis of irrigation practices in Maharashtra, India. *Hydrol. Sci. J.* 69, 1586–1603. doi: 10.1080/02626667.2024.2376709

Ahmad, D., Afzal, M., and Rauf, A. (2019). Analysis of wheat farmers' risk perceptions and attitudes: evidence from Punjab, Pakistan. *Nat. Hazards* 95, 845–861. doi: 10.1007/s11069-018-3523-5

Alam, M. A., and Guttormsen, A. G. (2019). Risk in aquaculture: farmers' perceptions and management strategies in Bangladesh. *Aquacult. Econ. Manag.* 23, 359–381. doi: 10.1080/13657305.2019.1641568

Asare-Nuamah, P., Antwi-Agyei, P., Dick-Sagoe, C., and Adeosun, O. T. (2022). Climate change perception and the adoption of innovation among mango plantation farmers in the Yilo Krobo municipality, Ghana. *Environ. Dev.* 44:100761. doi: 10.1016/j.envdev.2022.100761

Belaidi, S., Chehat, F., and Benmehaia, M. A. (2022). The adoption of water-saving irrigation technologies in the Mitidja plain, Algeria: an econometric analysis. *New Medit.* 21, 53–73. doi: 10.30682/nm2201d

Bommier, A., and Le Grand, F. (2019). Risk aversion and precautionary savings in dynamic settings. *Manage. Sci.* 65, 1386–1397. doi: 10.1287/mnsc.2017.2959

Dai, X., Chen, J., Chen, D., and Han, Y. (2015). Factors affecting adoption of agricultural water-saving technologies in Heilongjiang Province, China. *Water Policy* 17, 581–594. doi: 10.2166/wp.2015.051

Du, J., Yang, P-. L., Ren, S-. M., Li, Y-. K., Wang, Y-. Z., Yuan, X-. Q., et al. (2011). Effects of canal-lining project on groundwater and ecological environment in Hetao Irrigation District of Inner Mongolia. *Ying Yong Sheng Tai Xue Bao* 22, 144–150. doi: 10.13287/j.1001-9332.2011.0180%24

Fahad, S., Wang, J., Khan, A. A., Ullah, A., Ali, U., Hossain, M. S., et al. (2018). Evaluation of farmers' attitude and perception toward production risk: lessons from Khyber Pakhtunkhwa Province, Pakistan. *Human Ecol. Risk Assess. Int. J.* 24, 1710–1722. doi: 10.1080/10807039.2018.1460799

Farhan, M., Yasin, M. A., Bakhsh, K., Ali, R., Ullah, S., Munir, S., et al. (2022). Determinants of risk attitude and risk perception under changing climate among farmers in Punjab, Pakistan. *Nat. Hazards* 114, 2163–2176. doi: 10.1007/s11069-022-05465-x

Finger, R., Hediger, W., and Schmid, S. (2011). Irrigation as adaptation strategy to climate change—a biophysical and economic appraisal for Swiss maize production. *Clim. Change* 105, 509–528. doi: 10.1007/s10584-010-9931-5

Foster, A. D., and Rosenzweig, M. R. (2010). Microeconomics of technology adoption. *Annu. Rev. Econom.* 2, 395–424. doi: 10.1146/annurev.economics.102308.124433

Gabiri, G., Diekkrger, B., Leemhuis, C., Burghof, S., Naeschen, K., Asiimwe, I., et al. (2018). Determining hydrological regimes in an agriculturally used tropical inland valley wetland in Central Uganda using soil moisture, groundwater, and digital elevation data. *Hydrol. Process.* 32, 349–362. doi: 10.1002/hyp.11417

Garcia, S. N., Osburn, B. I., and Jay-Russell, M. T. (2020). One health for food safety, food security, and sustainable food production. *Front. Sustain. Food Syst.* 4:1. doi: 10.3389/fsufs.2020.00001

Hanger-Kopp, S., and Palka, M. (2020). "Exploring drought resilience through a drought risk management lens in Austria," in *Disaster Risk Reduction and Resilience*, eds. F. M. F. Vanclay (Leeds: Emerald Publishing Limited), 115–138.

Hanger-Kopp, S., and Palka, M. (2022). Decision spaces in agricultural risk management: a mental model study of Austrian crop farmers. *Environ. Dev. Sustain.* 24, 6072–6098. doi: 10.1007/s10668-021-01693-6

Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., et al. (2019). Climate risk management and rural poverty reduction. *Agric. Syst.* 172, 28–46. doi: 10.1016/j.agsy.2018.01.019

Hatch, N. R., Daniel, D., and Pande, S. (2022). Behavioral and socio-economic factors controlling irrigation adoption in Maharashtra, India. *Hydrol. Sci. J.* 67, 847–857. doi: 10.1080/02626667.2022.2058877

Hellerstein, D., Higgins, N., and Horowitz, J. (2013). The predictive power of risk preference measures for farming decisions. *Eur. Rev. Agricult. Econ.* 40, 807–833. doi: 10.1093/erae/jbs043

Holt, C. A., and Laury, S. K. (2002). Risk aversion and incentive effects. *Am. Econ. Rev.* 92, 1644–1655. doi: 10.1257/000282802762024700

Hong, X., Chen, Y-. J., Gong, Y., and Wang, H. (2024). Farmers' green technology adoption: Implications from government subsidies and information sharing. *Nav. Res. Logist.* 71, 286–317. doi: 10.1002/nav.22150

Hossain, M. S. (2025). Assessing smallholder farmers' flood risk behavior and their willingness to pay for crop insurance as a risk coping strategy in northern Bangladesh. *Nat. Haz.* 121, 4191–4217. doi: 10.1007/s11069-024-06958-7

Javed, T., and Khan, I. (2019). Farm households' risk perception, attitude and adaptation strategies in dealing with climate change: promise and perils from rural Pakistan. *Land Use Policy* 91:104395. doi: 10.1016/j.landusepol.2019.104395

Koundouri, P., Nauges, C., and Tzouvelekas, V. (2005). Endogenous technology adoption under production risk: theory and application to irrigation technology. *Econ. Transit.* 13, 343–369.

Li, L., and Huang, Y. (2023). Sustainable agriculture in the face of climate change: exploring farmers' risk perception, low-carbon technology adoption, and productivity in the Guanzhong Plain of China. *Water* 15:3290. doi: 10.3390/w15122228

Liu, H., Chen, Z., Wen, S., Zhang, J., and Xia, X. (2025). Impact of digital literacy on farmers' adoption behaviors of green production technologies. *Agriculture* 15:114. doi: 10.3390/agriculture15030303

Liu, Y., Yang, Y., Lai, X., Huang, Y., and Gitonga, J. N. (2025). Study on farmers' willingness to pay for water saving irrigation technology and its influencing factors: based on the choice experiment of Zhangye city, Gansu province in China. *Water Policy* 27, 21–43. doi: 10.2166/wp.2025.073

Lucas, M. P., and Pabuayon, I. M. (2011). Risk perceptions, attitudes, and influential factors of rainfed lowland rice farmers in Ilocos Norte, Philippines. *Asian J. Agricult. Dev.* 8, 61–77. doi: 10.37801/ajad2011.8.2.5

Lybbert, T. J., and Sumner, D. A. (2012). Agricultural technologies for climate change in developing countries: policy options for innovation and technology diffusion. *Food Policy* 37, 114–123. doi: 10.1016/j.foodpol.2011.11.001

Menapace, L., Colson, G., and Raffaelli, R. (2016). A comparison of hypothetical risk attitude elicitation instruments for explaining farmer crop insurance purchases. *Eur. Rev. Agricult. Econ.* 43, 113–135. doi: 10.1093/erae/jbv013

Mu, L., Luo, C., Li, Y., Tan, Z., and Gao, S. (2024). 'They adopt, I also adopt': The neighborhood effects and irrigator farmers' conversion to adopt water-saving irrigation technology. *Agricult. Water Manag.* 305:109159. doi: 10.1016/j.agwat.2024.109141

Olarinde, L. O., Manyong, V. M., and Akintola, J. O. (2007). Attitudes towards risk among maize farmers in the dry savanna zone of Nigeria: some prospective policies for improving food production. *Afr. J. Agric. Res.* 2, 399–408.

Ricart, S., Gandolfi, C., and Castelletti, A. (2024). How do irrigation district managers deal with climate change risks? Considering experiences, tipping points, and risk normalization in northern Italy. *Clim. Risk Manag.* 44:100598. doi: 10.1016/j.crm.2024.100598

Salhi, S., Imache, A., Tonneau, J-. P., and Ferfera, M-. Y. (2012). Determinants of conversion to drip irrigation systems by farmers: the case of the Mitidja plain in Algeria. *Cahiers Agricult.* 21, 417–426. doi: 10.1684/agr.2012.0598

Shi, R., Wang, G., Zhang, X., Xu, Y., Wu, Y., Wu, W., et al. (2022). Determination of the effective utilization coefficient of irrigation water based on geographically weighted regression. *Front. Earth Sci.* 16, 401–410. doi: 10.1007/s11707-021-0939-0

Singh, G., Gandhi, V. P., and Jain, D. (2024). Micro-irrigation adoption and the Jevons' Paradox: a study from four states of India. *Agricult. Water Manag.* 303:108993. doi: 10.1016/j.agwat.2024.109040

Sitkin, S. B., and Weingart, L. R. (1995). Determinants of risky decision-making behavior: a test of the mediating role of risk perceptions and propensity. *Acad. Manag. J.* 38, 1573–1595. doi: 10.2307/256844

Suchato, P., Mieno, T., Schoengold, K., and Foster, T. (2022). The potential for moral hazard behavior in irrigation decisions under crop insurance. *Agricult. Econ.* 53, 257–273. doi: 10.1111/agec.12676

Tang, J., Folmer, H., and Xue, J. (2016). Adoption of farm-based irrigation water-saving techniques in the Guanzhong Plain, China. *Agricult. Econ.* 47, 445–455. doi: 10.1111/agec.12243

Torkamani, J., and Shajari, S. (2008). Adoption of new irrigation technology under production risk. *Water Resour. Manag.* 22, 229–237. doi: 10.1007/s11269-007-9154-3

Tzachor, A., Devare, M., King, B., Avin, S., and Heigeartaigh, S. O. (2022). Responsible artificial intelligence in agriculture requires systemic understanding of risks and externalities. *Nat. Mach. Intell.* 4, 104–109. doi: 10.1038/s42256-022-00440-4

Ullah, R., Shivakoti, G. P., Zulfiqar, F., Iqbal, M. N., and Shah, A. A. (2017). Disaster risk management in agriculture: tragedies of the smallholders. *Nat. Hazards* 87, 1361–1375. doi: 10.1007/s11069-017-2821-7

Vågsholm, I., Arzoomand, N. S., and Boqvist, S. (2020). Food security, safety, and sustainability—getting the trade-offs right. *Front. Sustain. Food Syst.* 4:487217. doi: 10.3389/fsufs.2020.00016

van Winsen, F., Mey, d. e., Lauwers, Y., Van Passel, L., and Vancauteren, S. M., and Wauters, E. (2016). Determinants of risk behaviour: effects of perceived risks and risk attitude on farmer's adoption of risk management strategies. *J. Risk Res.* 19, 56–78. doi: 10.1080/13669877.2014.940597

Villacis, A. H., Alwang, J. R., and Barrera, V. (2021). Linking risk preferences and risk perceptions of climate change: a prospect theory approach. *Agricult. Econ.* 52, 863–877. doi: 10.1111/agec.12659

Wang, G., and Xu, M. (2024). The role of social interaction in farmers' water-saving irrigation technology adoption: testing farmers' interaction mechanisms. *Sci. Rep.* 14:1547. doi: 10.1038/s41598-024-76620-6

Wang, H., Huang, J., Zhou, H., Deng, C., and Fang, C. (2020). Analysis of sustainable utilization of water resources based on the improved water resources ecological footprint model: a case study of Hubei Province, China. *J. Environ. Manage.* 262:110332. doi: 10.1016/j.jenvman.2020.110331

Wang, Y., Huang, J., Wang, J., and Findlay, C. (2018). Mitigating rice production risks from drought through improving irrigation infrastructure and management in China. *Aust. J. Agricult. Resour. Econ.* 62, 161–176. doi: 10.1111/1467-8489.12241

Wang, Y., Wang, Z., Zhao, M., and Li, B. (2024). The influence of technology perceptions on farmers' water-saving irrigation technology adoption behavior in the North China Plain. *Water Policy* 26, 170–188. doi: 10.2166/wp.2024.170

Wauters, E., Van Winsen, F., and de Mey, Y. L. (2014). Risk perception, attitudes towards risk and risk management: evidence and implications original paper. *Agricult. Econ.* 60, 110–120. doi: 10.17221/176/2013-AGRICECON

Wibowo, R. P., Rizaldi, T., Sumono, and Siregar, I. (2019). The impact of risk and uncertainty on irrigation decision for paddy production in North Sumatera Indonesia. *IOP Conf. Ser. Mat. Sci. Eng.* 648:012040. doi: 10.1088/1757-899X/648/1/012040

Xiuling, D., Qian, L., Lipeng, L., and Sarkar, A. (2023). The impact of technical training on farmers adopting water-saving irrigation technology: an empirical evidence from China. *Agriculture* 13:470. doi: 10.3390/agriculture13050956

Xu, X., Huang, G., Qu, Z., and Pereira, L. S. (2010). Assessing the groundwater dynamics and impacts of water saving in the Hetao Irrigation District, Yellow River basin. *Agricult. Water Manag.* 98, 301–313. doi: 10.1016/j.agwat.2010.08.025

Yang, Y., Zhang, Y., Zhou, J., Liu, Y., Lin, L., Kang, S., et al. (2025). Climate change risk perception as a catalyst for adaptive effect of ICT: the case in rural Eastern China. *Clim. Risk Manag.* 48:100650. doi: 10.1016/j.crm.2025.100697

Yu, X., Sheng, G., Sun, D., and He, R. (2024). Effect of digital multimedia on the adoption of agricultural green production technology among farmers in Liaoning Province, China. *Sci. Rep.* 14:7484. doi: 10.1038/s41598-024-64049-w

Zhang, J., Guan, K., Peng, B., Pan, M., Zhou, W., Jiang, C., et al. (2021). Sustainable irrigation based on co-regulation of soil water supply and atmospheric evaporative demand. *Nat. Commun.* 12:594. doi: 10.1038/s41467-021-25254-7

Zhang, J., and Song, J. (2024). The impact of government support and farmers' pro-environmental intention on water-saving irrigation techniques adoption: evidence using propensity score matching. *Water Policy* 26, 154–169. doi: 10.2166/wp.2024.089

Zou, X., Li, Y. -e., Gao, Q., and Wan, Y. (2012). How water saving irrigation contributes to climate change resilience-a case study of practices in China. *Mitig. Adapt. Strateg. Glob. Chang.* 17, 111–132. doi: 10.1007/s11027-011-9316-8