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Evaluating the impact of peer effects and social trust on water-saving irrigation technology adoption by watermelon growers: a case study of two provinces in the Yellow River irrigation region, China

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Introduction: Excessive use of water resources has resulted in severe soil erosion in China's Yellow River irrigation region, posing a critical constraint on ecological restoration and sustainable agricultural development. Enhancing the adoption rate of water-saving irrigation technologies and promoting rational water use remain pressing challenges.

Methods: Drawing upon perspectives from sociology and behavioral economics, this study elucidates the mechanisms through which peer effects and social trust influence farmers' adoption of water-saving irrigation technologies. Empirical analysis is based on survey data from 716 households in major fruit-producing areas of Shaanxi and Shanxi provinces, collected in 2020.

Results: (1) Peer effects significantly facilitate the adoption of water-saving irrigation technologies, increasing the probability and intensity of adoption by 15 and 9.23%, respectively. (2) Among the dimensions of social trust, interpersonal trust exerts a statistically significant positive influence on adoption behavior, raising the probability and intensity of adoption by approximately 6 and 4.46%, respectively. Institutional trust increases the likelihood of adoption by 3.56%. (3) A complementary relationship exists between peer effects and interpersonal trust in shaping farmers' adoption behaviors, whereas peer effects and institutional trust demonstrate a substitutive relationship in influencing both the adoption and its intensity. (4) Peer effects and institutional trust exhibit functional homogeneity, both contributing to increased adoption by reducing the perceived difficulty of accessing relevant technologies.

Discussion and insights: Based on these findings, the study suggests leveraging peer effects in the diffusion of agricultural technologies, promoting model farmers to strengthen intergroup trust, expanding opportunities for mutual assistance and collaboration, and optimizing information dissemination channels. These strategies aim to enhance farmers' adoption of water-saving irrigation technologies, thereby contributing to ecological improvement and enhanced efficiency in agricultural water use.

KEYWORDS

mediation effect, peer effects, social trust, substitutive relationship, water-saving irrigation technologies

1 Introduction

Water resources are a pivotal environmental factor in sustaining and promoting sustainable agricultural development (Abdelzaher and Awad, 2022). As the sector with the highest demand for water resources, agriculture accounted for 61.6% of China's total water usage in 2021, with efficient water use in agriculture playing a critical role in the maintenance and sustainable development of the economy, society, and ecological environment (Zhang et al., 2006; Iyiola et al., 2024). However, the overexploitation and irrational use of water resources have become significant constraints on sustainable agricultural development and socio-economic stability (Yao et al., 2021; Huang et al., 2025). Notably, the Yellow River Basin covers an area of 795,000 km², with most regions located in arid and semi-arid zones. Its multi-year average precipitation is only 456 mm, and the per capita water resource volume is less than a quarter of the national average, far below the internationally recognized extreme water scarcity standard of 500 m³ per capita. In 2024, the annual precipitation in the Yellow River Basin was merely 537.6 mm, with a total water resource volume of 82.71 billion m³, accounting for only 2.6% of the national total. The total water consumption reached 40.178 billion m³, of which agricultural water use was 25.469 billion m³, accounting for 63.4%. The effective utilization coefficient of farmland irrigation water was only 0.58, while the regional soil erosion area was 245,800 km², directly damaging regional agricultural productivity and the sustainable development of the ecosystem (Ye and Qu, 2025; Xie et al., 2025; Xue and Chen, 2023). Issues such as low water use efficiency in agriculture, extensive irrigation practices, and soil salinization further exacerbate the damage to the local hydroecological environment and agricultural economic development (Mi et al., 2016; Xu et al., 2011).

Water-saving irrigation technologies have been widely applied in agricultural production, each with a well-defined functional orientation, and their adaptability to cash crops such as watermelons is particularly critical. At present, the typical water-saving irrigation technologies extensively used in agricultural production mainly fall into four categories: drip irrigation, sprinkler irrigation, micro-sprinkler irrigation and subsurface drip irrigation, with significant differences in their application effects and suitable scenarios for crop cultivation. As a core type of precision irrigation, drip irrigation delivers water and fertilizers precisely to the rhizosphere of watermelon plants through emitters, reducing ineffective evaporation and seepage by 30–50% (Ashour et al., 2025; Savari et al., 2025). It aligns with the characteristics of watermelons, such as shallow root systems and high water demand, ensuring stable soil moisture during the fruit expansion stage and alleviating drought stress. Sprinkler irrigation and micro-sprinkler irrigation achieve uniform water distribution in the field through atomized water supply, regulate the canopy microclimate, and mitigate high-temperature induced diseases, making them suitable for large-scale and flat planting areas such as the Yellow River Irrigation Region (Zheng et al., 2025; Huang et al., 2025). Subsurface drip irrigation involves burying drip lines 10–20 cm below the ground surface, which further reduces water loss and prevents emitter clogging, and is thus adapted to arid and semi-arid areas in northern China (Hu et al., 2025; Liu et al., 2025). These

technologies not only alleviate the contradiction between the high water demand of watermelons and regional water resource scarcity, but also improve the physical and chemical properties of soil and enhance fruit quality. However, field surveys show that only 27.93% of the sampled farmers have adopted such technologies (Table 1), and the majority still rely on traditional flood irrigation. The main reasons include information asymmetry, high initial investment and insufficient technical cognition (Savari et al., 2025; Nazari et al., 2018; Shang et al., 2025; Chen, 2011). This not only results in a huge waste of water resources, but also exacerbates soil degradation and restricts the sustainable development of the agricultural industry (Ashour et al., 2025; Zheng et al., 2025; Huang et al., 2025). Therefore, exploring the factors influencing farmers' technology adoption and identifying the bottlenecks in promotion are of great practical significance for advancing the popularization of water-saving irrigation and the sustainable development of agriculture.

Water-saving irrigation technologies serve as effective means to reconcile the contradictions between the natural environment and socio-economic sustainable development (Xu et al., 2019), offering the advantages of conserving water resources and improving the efficiency of agricultural water use, effectively alleviating water scarcity and the tension in agricultural water usage (Chen et al., 2020). China's No. 1 Central Document of 2021 emphasizes the need to vigorously promote sustainable agricultural development, actively disseminate water-saving agriculture, and comprehensively manage agricultural non-point source pollution. Therefore, improving the efficiency of agricultural water use is an important avenue to achieve sustainable water use in agriculture. The process of farmers adopting water-saving irrigation technologies includes obtaining related information, learning basic operations, purchasing irrigation equipment, installing pipelines, and maintenance, among other steps (Mallareddy et al., 2023). Farmers themselves often face the challenges of information asymmetry, weak risk resistance, and high transaction costs for technology and equipment, which greatly diminish the enthusiasm of the technology adopters. Therefore, in the current context of China's economy entering a high-quality development stage and the sustainable development of agriculture, exploring the influencing factors on farmers' adoption of water-saving irrigation technologies, and then resolving the constraints and barriers to technology adoption, is of great significance for establishing a long-term mechanism for the diffusion and promotion of agricultural technologies (Lakhier et al., 2024).

Existing studies on farmers' adoption of water-saving irrigation technologies have mainly focused on two perspectives. On the one hand, based on the "rational economic agent" hypothesis of farmer behavior theory, scholars argue that individual farmer

TABLE 1 Differences in peer effects and social trust between non-adopters and adopters.

Variable	Adopters	Non-adopters	Mean difference
Peer effects	14.509 (0.842)	14.322 (0.817)	0.990***
Interpersonal trust	5.972 (1.272)	5.443 (1.023)	0.544***
Institutional trust	2.457 (1.123)	2.443 (1.108)	0.226*

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors.

decision-making mainly depends on the trade-off between technology adoption costs and expected benefits, and profit maximization is the core driver (Zou et al., 2013). Relevant studies have verified the significant impacts of farmland operation scale, technology application cost, and adoption effect on farmers' adoption decisions (Wang et al., 2024; Seo et al., 2008; Hu et al., 2022; Koutsou et al., 2014). For cash crops such as watermelons, existing research has noted that their high water demand and sensitivity to irrigation quality make farmers' technology adoption decisions more dependent on cost-benefit calculations and risk assessments (Zhou et al., 2008; Mojid and Mainuddin, 2021). For example, Zhou et al. (2008) found that the high initial investment of water-saving irrigation technologies is a key constraint for watermelon growers in North China (Liu et al., 2025), while Mojid and Mainuddin (2021) pointed out that watermelon farmers' adoption of drip irrigation is significantly affected by the expected yield-increasing effect, as the crop's economic value is closely tied to water supply stability (Mojid and Mainuddin, 2021). On the other hand, from the perspective of behavioral economics, scholars have emphasized that psychological characteristics should be incorporated into individual decision-making analysis under uncertain conditions to improve the comprehensiveness and scientificity of research (Cui et al., 2022). Corresponding studies have shown that farmers' technology cognition, risk attitude, and external environment cognition significantly affect their adoption of water-saving irrigation technologies (Seo et al., 2008; Hu et al., 2022; Monge and Daniel, 2008; Xiuling et al., 2023). For watermelon growers specifically, Wang et al. (2024) confirmed that farmers' perceived usefulness of water-saving technologies (e.g., reducing labor input for irrigation) has a positive impact on adoption willingness, while Hu et al. (2022) found that risk-averse watermelon farmers are less likely to adopt new irrigation technologies due to concerns about operational complexity.

Despite the aforementioned research progress, the current understanding of how peer effects and social trust specifically influence watermelon growers' adoption of water-saving irrigation technologies remains limited. First, most studies have treated peer effects as a homogeneous concept, failing to clarify how peer interactions (e.g., information sharing, behavior imitation) specifically shape the adoption decisions of cash crop growers with distinct production characteristics (e.g., higher water demand, more sensitive to irrigation efficiency) (Zhou et al., 2020; Amadu, 2023; Meng et al., 2023). Second, social trust is often measured as a single dimension in existing literature, with insufficient attention to whether different types of trust (e.g., interpersonal trust vs. institutional trust) exert heterogeneous effects on technology adoption, or how they interact with peer effects to influence decision-making (Skevas et al., 2022; Lee et al., 2021; Wang and Luo, 2024; Wang and Yang, 2024; De Vries et al., 2019). Third, the underlying mechanisms through which peer effects and social trust jointly affect adoption behavior. Such as whether they reduce perceived risks, lower information costs, or enhance behavioral norms, have not been systematically explored in the context of watermelon growers in water-scarce regions. These limitations hinder the formulation of targeted policies to promote water-saving irrigation technologies among this specific group. To address the above limitations and clearly articulate the specific research gaps, this study identifies three unresolved issues based on a systematic literature review: First, Research object gap. Most existing studies focus on general grain farmers, while targeted research on cash crop growers (especially watermelon growers) is scarce. Compared with grain crops, watermelon has higher water demand and a more sensitive response to irrigation methods, meaning the

decision-making logic of watermelon growers in adopting water-saving irrigation technologies may differ significantly from that of grain farmers. Ignoring this specific group leads to incompleteness in the theoretical system of agricultural water-saving technology adoption. Second, Influencing factor gap. Although some studies have noted the role of peer effects and social trust in farmers' decision-making, most discuss these two factors independently. Few studies explore the interactive effect between peer effects and different types of social trust (interpersonal vs. institutional trust) on the adoption of water-saving irrigation technologies. In fact, social trust may act as a "catalyst" or "moderator" for peer effects, high interpersonal trust can enhance information transmission efficiency and behavior imitation willingness among peers, while institutional trust may either complement or substitute for peer effects depending on the level of institutional support. Third, Research region gap. The Yellow River Irrigation Region is an important agricultural production base in China with prominent water shortages and an urgent need for water-saving irrigation technologies. However, existing studies on this region are relatively scattered, lacking systematic empirical research based on multi-provincial sample data. This makes it difficult to provide targeted policy support for promoting water-saving irrigation technologies in this key region.

To clarify core concepts, peer effect in this study refers to the influence of farmers' peers (e.g., neighboring growers, members of the same agricultural cooperative) on their adoption decisions through information sharing, experience communication, and behavior imitation (Seo et al., 2008; Hu et al., 2022; Cui et al., 2022). Interpersonal trust denotes mutual trust between farmers and their peers, relatives, or villagers, forged through long-term social interactions. Institutional trust refers to farmers' trust in government departments, agricultural technology extension institutions, and related policies, as reflected in their recognition of the credibility and effectiveness of these entities (Skevas et al., 2022; Lee et al., 2021; Wang and Luo, 2024; Wang and Yang, 2024). These concepts align with the core connotations in existing literature while being refined to fit the specific context of cash crop growers in water-scarce regions.

In view of the above research gaps and core concept definitions, this study holds that peer effects and social trust (including interpersonal and institutional trust) may be the key factors determining watermelon growers' adoption of water-saving irrigation technologies, and their interaction may also have an important regulatory role. Therefore, this paper constructs an analytical framework for farmers' adoption of water-saving irrigation technologies from the perspectives of peer effects and social trust (including interpersonal and institutional trust), combined with the current situation of sample farmers in the surveyed region. Using survey data from 716 watermelon growers in Xi'an, Shaanxi Province, and Yuncheng, Shanxi Province (two typical regions in the Yellow River Irrigation Region), a two-stage regression model is used to analyze the influence of peer effects, social trust, and their interaction terms on farmers' adoption of water-saving irrigation technologies (including adoption probability and adoption intensity). On this basis, the paper further conducts a heterogeneity analysis of farmers' adoption of water-saving irrigation technologies from the aspects of scale difference and cultural difference, aiming to fill the above-mentioned research gaps. The research results are expected to provide targeted reference and insight for optimizing watermelon growers' technology adoption decision-making behavior, improving regional water-saving agricultural policies, and promoting sustainable agricultural development in the Yellow River Irrigation Region.

2 Theoretical analysis and research hypotheses

2.1 The impact of peer effects on farmers' adoption behavior of water-saving irrigation technology

The concept of group behavior was initially proposed by Banerjee (1992) and Baddeley (2010) defined it as the phenomenon where individual decisions follow and imitate group behavior rather than make independent choices based on their own information (Prager and Posthumus, 2010; Yuan et al., 2022), considering it the safest behavior, which is reflexive and does not require rational intervention (He et al., 2018). According to group behavior theory, peer effects refer to the idea that an individual's behavior is not only influenced by their own characteristics but also by the behaviors and characteristics of other individuals in their group (Banerjee, 1992; Baddeley, 2010). Essentially, an individual agent in the decision-making process will consider the decisions and outcomes of other agents. In recent years, the application of peer effects has expanded from social psychology to the field of behavioral economics, and existing literature demonstrates that farmers are influenced by other associated farmers in many agricultural production and management decisions, such as agricultural production investments, with target farmers usually choosing behavior strategies consistent with those of other farmers in their group (Sun, 2013; Rimal, 2008). The impact of this effect on the adoption of technology by farmers is mainly reflected in the following three mechanisms: The first is the catch-up imitation mechanism. The decision of farmers to adopt water-saving irrigation technology is not made in isolation; it depends not only on their own characteristics such as land endowment, household economic level, and human capital, but also on the degree of technology adoption by other farmers in their group. Under the influence of a fear of lagging behind, farmers use the relative level of adoption by others in the group as a basis for their own decision-making through imitation learning, thereby increasing the rate of adoption of water-saving irrigation technologies (Di Falco et al., 2020; Falk and Ichino, 2006). The second and third mechanisms involve information acquisition and risk aversion. Due to farmers' bounded rationality and aversion to uncertainty and risk, short-term household income maximization is often the starting point for farmers adopting water-saving irrigation technologies. Therefore, farmers refer to the cost-benefit situations and adoption effects of other technology adopters in the group, acquiring prior information about the adoption of water-saving irrigation technologies through social interaction. This saves on the costs of searching for and obtaining information and significantly reduces the uncertainty and risk associated with the adoption of water-saving irrigation technologies, thereby promoting adoption.

Hypothesis 1: Peer effects can significantly promote the adoption behavior of farmers' water-saving irrigation technologies.

2.2 The impact of social trust on farmers' adoption behavior of water-saving irrigation technology

Based on the social embeddedness theory, farmers are not only "rational economic agents" pursuing profit maximization but also

"social beings" embedded in social relational networks, whose decisions are easily constrained by external environments such as social interactions and interpersonal relationships (He et al., 2023). As the core of social capital, social trust is a key prerequisite for reciprocal cooperation in communities (Krishnan and Patnam, 2014), essentially serving as a relational regulatory mechanism that influences decision-making by reducing transaction costs and alleviating information asymmetry (Skevas et al., 2022; Lee et al., 2021). Due to the heterogeneity in farmers' behavioral motivations and social relationships, the two dimensions of social trust, interpersonal trust and institutional trust, form differentiated influence paths on the adoption of water-saving irrigation technologies.

Interpersonal trust is bonded by emotional connections, manifested as mutual trust among farmers within acquaintance networks such as relatives and neighbors. Its promotional effects are achieved through three mechanisms: First, improved information transmission efficiency. Under high trust, farmers are willing to share real experiences such as drip irrigation maintenance and micro-sprinkler irrigation water-saving effects. This "word-of-mouth" communication reduces information search costs and enhances technology credibility, which is particularly crucial for small-scale farmers. Second, construction of cooperative mutual assistance networks. Costs are shared through collective actions such as centralized procurement and joint pipeline laying, for instance, trusted groups can obtain bulk discounts by jointly purchasing subsurface drip irrigation equipment. Third, behavioral imitation and norm formation. The demonstration effect of successful adoption by acquaintances is amplified, and at the same time, an implicit norm that "adopting water-saving technology is a responsible behavior" is formed, promoting diffusion through group pressure and reputation incentives. Based on this, Hypothesis 2 is proposed.

Hypothesis 2: Interpersonal trust can significantly promote farmers' adoption behavior of water-saving irrigation technologies (both adoption probability and adoption intensity).

Institutional trust is rooted in the government's institutional environment, reflecting farmers' trust in government departments, agricultural technology extension institutions, and related policies (Dai et al., 2015; Mojid and Mainuddin, 2021; Wang et al., 2024; Seo et al., 2008). Its influence mechanisms include: first, alleviating information asymmetry. Governments and agricultural technology departments transmit key information such as technological advantages and subsidy standards through policy documents and technical training, reducing farmers' concerns about policy and technology reliability. Second, sharing risks and costs. Subsidies for equipment purchase and installation ease the financial constraints of small-scale farmers, while free training and maintenance guidance address the problems of "not knowing how to use" and "not using well." Third, guiding behavior and shaping norms. By promoting the ecological value of technologies, it breaks the short-term profit-oriented mindset; through quality supervision and dispute resolution mechanisms, it protects farmers' legitimate rights and interests, strengthens their willingness to comply with policies, and thus drives technology adoption. Based on this, Hypothesis 3 is proposed.

Hypothesis 3: Institutional trust can significantly promote farmers' adoption behavior of water-saving irrigation technologies.

2.3 The interactive effect of peer effects and social trust on farmers' adoption behavior of water-saving irrigation technologies

The academic community has extensively explored the role of peer effects in driving individual decision-making. Peer effects provide farmers with information channels, or that farmers engage in imitation learning through social interaction within similar groups, such as understanding the ecological and economic effects of water-saving irrigation technologies, learning the relevant operational knowledge and information. High levels of interpersonal trust can reduce information asymmetry between farmers and the group, increasing the efficiency of information dissemination and thus significantly promoting the adoption of water-saving irrigation technologies. However, when agricultural producers have limited information processing capabilities and must allocate attention across different information channels, the close communication under peer effects can have a substitutive effect with the institutional trust aspect of social trust in promoting the adoption of water-saving irrigation technologies.

Hypotheses 4 and 5: Peer effects and interpersonal trust have a complementary effect on farmers' adoption behavior of water-saving irrigation technologies; peer effects and institutional trust have a substitutive effect on farmers' adoption behavior of water-saving irrigation technologies.

3 Materials and methods

3.1 Data source

The research data for this paper come from household surveys conducted from December 2019 to January 2020 by the research team in the main fruit-producing areas of Shaanxi and Shanxi provinces. To ensure the rationality and representativeness of the sample selection of farming households, the research areas were established as the Yanhu District and Xia County in Yuncheng City, Shanxi Province, and the Yanliang District in Xi'an City, Shaanxi Province. A combined method of purposive sampling and random sampling was used to determine the surveyed households, with the following procedure: First, using purposive sampling, 10 towns from the Yanhu District and Xia County in Shanxi Province and 2 towns from the Yanliang District in Xi'an City, Shaanxi Province, were selected. Then, 1–15 villages were selected from each sample town. Finally, in each sample village, 6–28 watermelon or melon farming households were randomly chosen as survey subjects. Following the above sampling method, this survey visited 740 households across 12 towns and 33 villages in two districts and one county, completed 731 questionnaires, and ultimately obtained 716 valid questionnaires for this study, with a valid response rate of 97.14%.

Shaanxi and Shanxi provinces are ideal cases for this study due to three core reasons. First, regional relevance to the research theme: Both provinces are key parts of the Yellow River Irrigation Region, characterized by arid and semi-arid climates, scarce water resources, and a per capita water volume far below the national average. Agricultural water use accounts for 63.4% of the total water consumption in the Yellow River Basin, but the effective utilization coefficient

of farmland irrigation water is only 0.58, making the promotion of water-saving irrigation technologies an urgent practical demand. Second, representativeness of production characteristics: As major fruit-producing areas in China, watermelon cultivation is a pillar agricultural industry in both provinces. Watermelon has higher water demand and greater sensitivity to irrigation efficiency compared to grain crops, and local farmers still mainly use traditional flood irrigation, resulting in serious water waste. Their technology adoption dilemmas are typical of cash crop growers in water-scarce regions. Third, typicality of sample groups: The surveyed areas cover both suburban planting zones (such as Yanliang District of Xi'an) and remote rural areas (such as Xia County of Yuncheng), with significant differences in farmers' operation scale, age structure, and educational level. This ensures the diversity and representativeness of the sample, enabling the research conclusions to be extended to similar regions (Figure 1).

3.2 Variable definition and descriptive statistics

- (1) Dependent variables, in accordance with the academic community's definition of agricultural technology adoption behavior, include whether farmers adopt water-saving irrigation technologies and the extent of their adoption, which characterizes the adoption behavior of water-saving irrigation technologies by farmers. "Whether to adopt water-saving irrigation technologies" reflects the farmers' implementation and use of such technologies, while "the proportion of area under water-saving irrigation technology to the total farmland area of the household" further reflects the intensity of adoption by farmers and to some extent, the status of their adoption goals (Sun, 2013). The detailed information is shown in the attached Table A1.
- (2) Core explanatory variables. The core explanatory variables in this paper include peer effects and social trust. Previous studies have suggested that the adoption of water-saving irrigation technologies by other households in the same village can represent the variable of peer effects. Following these studies, this paper characterizes peer effects as "the situation of other farmers in the same village adopting water-saving irrigation technologies." As for the measurement of social trust, existing research posits that the sample farmers' trust in relatives, neighbors, and specific business entities can represent their social trust. For instance, Ji and Zhang (2021) used "reliability of borrowing money from relatives and friends" and "trust level in people they meet for the first time" to represent general and special trust (Hain et al., 2016), respectively; Tao et al. (2022), based on a study of organic fertilizer substitution behavior, measured interpersonal trust and institutional trust by the level of trust in relatives and friends and in the government, respectively (Hansen et al., 2002). This paper measures social trust by "the farmers' level of trust in strangers" and "the farmers' trust in government policies and propaganda regarding water-saving irrigation technologies" to gauge broad interpersonal trust and specific institutional trust. The detailed information is shown in the attached Table A1.
- (3) Control variables. The paper introduces control variables such as the difficulty of technology acquisition for water-saving irrigation, individual characteristics of household heads,

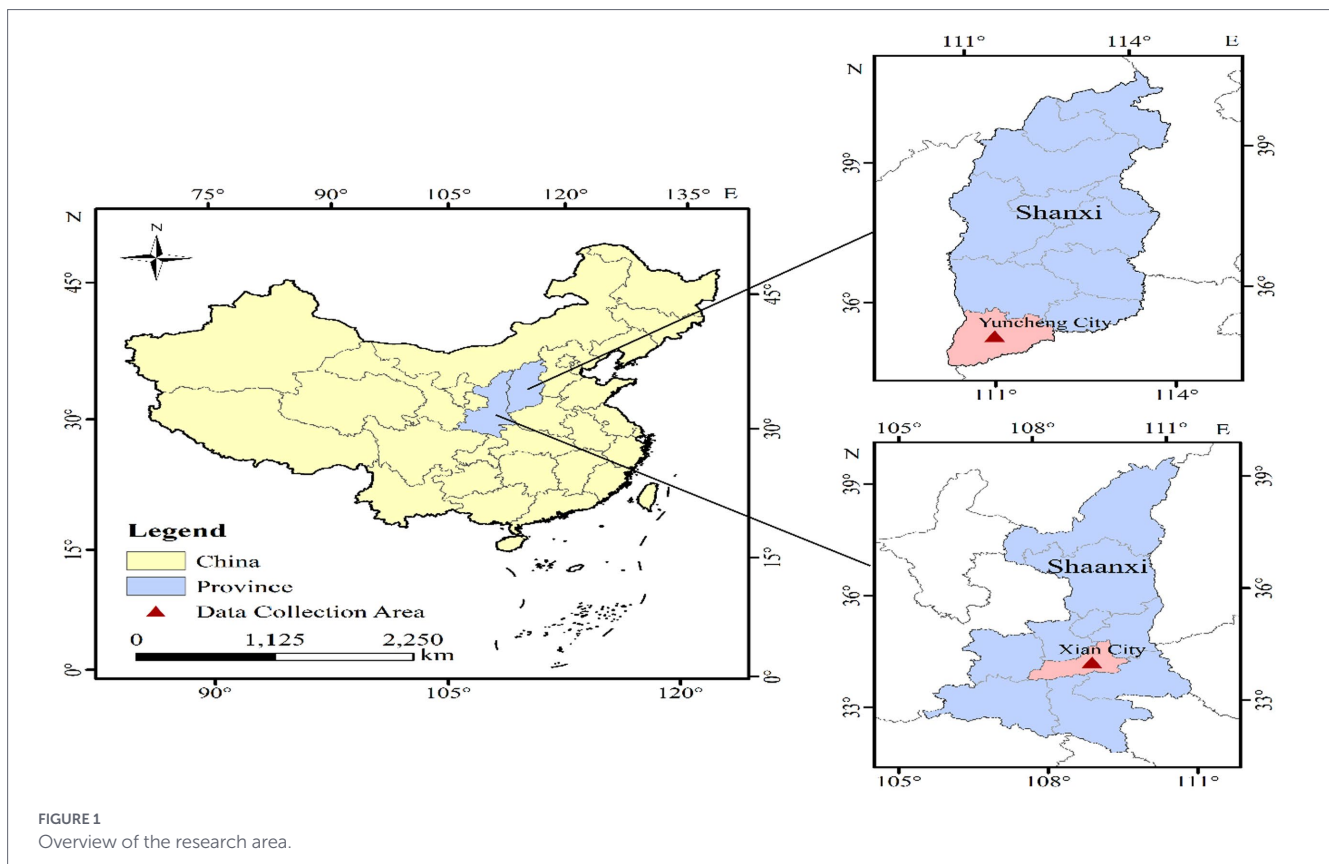


FIGURE 1
Overview of the research area.

family endowment characteristics, external environmental characteristics, and regional dummy variables. The difficulty of technology acquisition for water-saving irrigation is considered a significant constraining factor affecting farmers' adoption; the easier it is to access, the lower the cost of information search and acquisition, and the higher the likelihood and extent of adoption. Individual characteristics of the household head include age, educational level, and health status. Generally, the better the health of the household head, the greater the probability that the household will adopt water-saving irrigation technologies. The impacts of education level and age on the adoption of water-saving irrigation technologies or the intensity of adoption are uncertain. Family endowment characteristics include total household income, the number of laborers, farmland scale, and types of agricultural machinery owned. Typically, the more household income, the stronger the economic capacity of the farmer, the less the constraints of funds, and the higher the propensity and extent of adoption of water-saving irrigation technologies; the more family laborers and the larger the scale of farmland, the weaker the labor constraints, and the more likely the farmer is to adopt water-saving technologies to achieve scale effects and avoid risk losses. External environmental characteristics are represented by the impact of natural disasters. Natural shocks to farmers can affect their risk preferences and response capabilities, thereby affecting the adoption of water-saving irrigation technologies (McNiven and Gilligan, 2012). Moreover, there may be influences from regional differences; therefore, this paper further controls for location dummy variables to capture the impact of the aforementioned factors. Variable definitions and descriptive statistics are presented in Table 2.

3.3 Model settings

Prior to model estimation, a multicollinearity test was conducted to ensure the reliability of the regression results. Multicollinearity refers to a high degree of linear correlation between explanatory variables, which may lead to distorted coefficient estimates and reduced model interpretability. Given that this study includes multiple explanatory variables (e.g., peer effects, interpersonal trust, institutional trust) and control variables (e.g., age, educational level, farmland scale), potential multicollinearity issues may arise. To address this, the Variance Inflation Factor (VIF) was employed as the core test statistic. A VIF value greater than 10 indicates severe multicollinearity, while a VIF value less than 5 suggests no significant multicollinearity. The test results (see Appendix A for details) show that the VIF values of all explanatory variables and control variables are below 1.42, confirming that there is no significant multicollinearity among the variables in this study. This ensures the validity and robustness of the subsequent regression analysis results. To address the core research questions: Including whether farmers adopt water-saving irrigation technologies, the intensity of adoption, the interactive relationships between key factors, and the underlying mechanisms, this study employs four complementary analytical tools. They are organized in the order of Probit model, Tobit model, moderation effect analysis, and mediation effect analysis, with detailed explanations of their application rationales and working mechanisms below:

(1) Probit model and Tobit model

One core dependent variable of this study is "whether to adopt water-saving irrigation technology," which is a binary choice with only two outcomes (adopt = 1, not adopt = 0). Standard linear models (e.g.,

TABLE 2 Variable definitions.

Variable	Definition and assignment
Adoption decision	Whether the farmer has adopted water-saving irrigation technology: Adopted = 1, Not adopted = 0
Adoption intensity	The proportion of the area under water-saving irrigation technology to the total cultivated land area (%)
Peer effects	Adoption by surrounding individuals: Almost none = 1, Relatively few = 2, Average = 3, Quite a few = 4, Very many = 5
Interpersonal trust	Do you trust strangers: Never = 1, Relatively seldom = 2, Average = 3, Quite often = 4, Very often = 5
Institutional trust	Do you trust government policies and propaganda regarding water-saving irrigation technologies: Never = 1, Relatively seldom = 2, Average = 3, Quite often = 4, Very often = 5
Age	Age of the household head (years)
Educational level	Years of education received by the household head (years)
Health status	Health condition of the household head: Often ill = 1, Average = 2, Very good = 3
Total household income	Total household income of the farmer in 2019 (10,000 yuan)
Family labor	Number of laborers in the farmer's household (individuals)
Farmland scale	Total cultivated land area currently managed by the family (Hectare)
Crop types	Variety of crops planted by the farmer's household: Melon = 1, Watermelon = 2
Agricultural machinery types	Types of agricultural machinery owned by the farmer's household (categories)
Risk attitude	If your family has a sum of money, into which type of project would you prefer to invest: High risk and high return = 1, Average risk and return = 2, Low risk and low return = 3, No risk and stable return = 4
Natural disasters	Whether the farmer has suffered from natural disaster impacts in the past 3 years: Yes = 1, No = 2
Difficulty of technology acquisition	Ease of acquiring relevant information and practical operation of water-saving irrigation technology: Very difficult = 1, Relatively difficult = 2, Average = 3, Quite easy = 4, Very easy = 5
Region	Farmer's location: Shaanxi = 0; Shanxi = 1

OLS) are inappropriate for such data, as they may produce predicted probabilities outside the 0–1 range (e.g., a probability of 1.2 or –0.3). The Probit model is specifically tailored for binary outcomes: it estimates the probability of adoption using a logistic distribution, ensuring results fall within 0–1, and provides interpretable marginal effects. This aligns perfectly with our goal of analyzing farmers' adoption decisions. The Probit model is like a “probability calculator” designed for yes/no questions. It takes factors such as peer effects and social trust as inputs, then outputs a likelihood (between 0 and 1) that a farmer will adopt the technology. The other core dependent variable is “adoption intensity” (the proportion of farmland under water-saving irrigation), which is a censored continuous variable. Many non-adopting farmers have an intensity of 0 (the lower bound), and the value cannot be negative. Standard linear models ignore this censoring and produce biased estimates (e.g., underestimating the impact of peer effects on adopters). The Tobit model addresses this limitation by simultaneously accounting for non-adopters (the 0 values) and the intensity of adoption among adopters, accurately estimating how factors influence the “degree” of adoption. This matches our goal of exploring both adoption decision and intensity. The Tobit model is designed for data with a “floor” (e.g., 0 for non-adopters). It treats non-adopters and adopters as a single group but “adjusts” for the fact that non-adopters cannot have negative intensity. When the dependent variable is “whether to adopt water-saving irrigation technology,” which represents a binary choice, a Probit model is chosen for estimation. When the dependent variable is “intensity of adoption of water-saving irrigation technology,” which is a censored continuous variable, a Tobit model is selected for estimation. The baseline model is specified as follows:

$$Wz_i = \alpha_0 + \alpha_1 effect_{peeri} + \alpha_2 interpersonal_{trusti} + \alpha_3 institutional_{trusti} + \beta control_i + \delta district_i + \varepsilon_i \quad (1)$$

In Equation (1) Wz_i denotes the farmer's behavior in adopting water-saving irrigation technology, including whether or not the technology is adopted and the intensity of adoption; $effect_{peeri}$ represents peer effects, $institutional_{trusti}$ and $interpersonal_{trusti}$ respectively represent interpersonal and institutional trust within social trust; $control_i$ represents other control variables that may affect the adoption of water-saving irrigation technology by farmers; $district_i$ is a regional dummy variable, and ε_i is the random disturbance term. $\alpha_1, \alpha_2, \alpha_3, \beta, \delta$ represent the regression coefficients corresponding to the explanatory variables.

(2) Moderation effect analysis

A core research gap of this study is exploring how different types of social trust (interpersonal vs. institutional trust) interact with peer effects to shape farmers' technology adoption. whether high interpersonal trust strengthens peer effects (complementary relationship) or high institutional trust reduces reliance on peer effects (substitutive relationship). Moderation effect analysis, implemented via interaction terms, is uniquely designed to quantify such conditional relationships, directly addressing our focus on the interactive dynamics between peer effects and social trust. Think of peer effects as a “push force” for adoption. Moderation effect analysis examines whether social trust acts as a “gear” that adjusts this push force. For example, if a farmer has high interpersonal trust in neighbors, they are more likely to follow peers' adoption behavior (the gear amplifies the push force). Conversely, if a farmer highly trusts government policies (institutional trust), they may rely less on peers' choices (the gear reduces the push force). Therefore, On this basis, the interaction terms between peer effects and interpersonal trust, as well as peer effects and

institutional trust, are further introduced to examine the potential functions or relationships of social trust and peer effects in the process of farmers' adoption of water-saving irrigation technology. A hierarchical regression analysis approach is employed, and the model is specified as follows:

$$Wz_i = \alpha_0 + \alpha_1 \text{effect}_{\text{Peeri}} + \alpha_2 \text{interpersonal}_{\text{trust}_i} + \alpha_3 \text{effect}_{\text{Peeri}} * \text{interpersonal}_{\text{trust}_i} + \beta \text{control}_i + \Gamma \text{district}_i + \varepsilon_i \quad (2)$$

$$Wz_i = \alpha_0 + \alpha_1 \text{effect}_{\text{Peeri}} + \alpha_2 \text{institutional}_{\text{trust}_i} + \alpha_3 \text{effect}_{\text{Peeri}} * \text{institutional}_{\text{trust}_i} + \beta \text{control}_i + \Gamma \text{district}_i + \varepsilon_i \quad (3)$$

In Equations (2, 3), $\text{effect}_{\text{Peeri}} * \text{interpersonal}_{\text{trust}_i}$ and $\text{effect}_{\text{Peeri}} * \text{institutional}_{\text{trust}_i}$ respectively denote the interaction terms between peer effects and interpersonal trust, and peer effects and institutional trust, with α_3 representing the regression coefficient for the interaction terms.

(3) Mediation effect analysis

Beyond identifying “whether” peer effects and social trust influence adoption, this study aims to uncover “how” they work, i.e., the indirect mechanisms. We hypothesize that “difficulty of technology acquisition” serves as a critical intermediate pathway: peer effects and social trust may reduce the difficulty of accessing technologies (e.g., via information sharing or policy support), thereby promoting adoption. Mediation effect analysis is the standard method to test such indirect causal chains, as it systematically verifies whether a variable (mediator) transmits the influence of independent variables to dependent variables, which is essential for enriching our mechanism-focused research. Imagine peer effects and social trust as “keys” to unlocking adoption. Mediation effect analysis checks if these keys first “unlock the door of technology acquisition difficulty” before opening the “door of adoption.” For example, peer effects help farmers learn operational skills from neighbors (reducing difficulty), and institutional trust provides clear policy guidance (also reducing difficulty), both paths ultimately lead to higher adoption rates. The analysis tests whether the “key” (peer effects/social trust) affects the “final outcome” (adoption) through the “intermediate step” (technology acquisition difficulty). The following mediation effect analysis model was specified:

$$Tf_i = \alpha_0 + \alpha_1 \text{effect}_{\text{Peeri}} + \alpha_2 \text{interpersonal}_{\text{trust}_i} + \alpha_3 \text{institutional}_{\text{trust}_i} + \beta \text{control}_i + \Gamma \text{district}_i + \varepsilon_i \quad (4)$$

$$Wz_i = \alpha_0 + \alpha_1 \text{effect}_{\text{Peeri}} + \alpha_2 \text{interpersonal}_{\text{trust}_i} + \alpha_3 \text{institutional}_{\text{trust}_i} + \kappa Tf_i + \beta \text{control}_i + \Gamma \text{district}_i + \varepsilon_i \quad (5)$$

In Equations (4, 5) Tf_i represents the difficulty of technology acquisition, and other explanatory variables have the same meaning as before. Drawing on the specific testing procedure for mediation effects proposed by Wen and Ye (2014), the existence of a mediation effect of the difficulty of technology acquisition was tested.

4 Results

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

4.1 Sample characteristics and group differences

(1) Basic characteristics of sample farming households

Table 3 presents the basic characteristics of the sample farming households and household heads. Looking at the individual characteristics of the household heads, they are predominantly middle-aged and older (accounting for 80.86% of the sample), with a low level of education; those with a junior high school education or less make up 87.29% of the total sample. The characteristics of the household heads are consistent with the situation in the survey area of Xi'an City. That is, the low-educated middle-aged and older population are the main labor force in agricultural production and management, with a significant outflow of young and middle-aged labor to non-agricultural work. From the perspective of the sample farming households' family characteristics, the number of family laborers is mainly between 2–5 people (accounting for 95.25% of the total sample), with an average of 3.3 laborers per family; 91.9% of the households operate farmland of 2 hectares or less, with an average farm size of 1.018 hectares, indicating a predominance of small-scale farmers. Overall, the sample is quite representative.

(2) Differences in peer effects and social trust between non-adopters and adopters

Table 1 further displays the differences between adopters and non-adopters of water-saving irrigation technologies in terms of peer effects and social trust. The results indicate significant disparities between adopters and non-adopters, with adopters exhibiting stronger peer effects and higher levels of interpersonal and institutional trust.

(3) Descriptive statistics

Table 4 presents the mean values and standard deviations of each variable, reflecting the characteristics related to the adoption of water-saving irrigation technologies by sample farming households. The mean value of Adoption Decision is 0.2793, indicating that approximately 27.93% of the sample farming households have adopted water-saving irrigation technologies. The overall adoption rate is relatively low, suggesting substantial potential for the promotion of this technology in the research area. The mean value of Peer Effects is 2.0028 with a standard deviation of 0.9372. Measured on a 5-point Likert scale, the mean value is close to the “relatively few” level, which means that the number of peers who have adopted the technology in the villages where most farmers reside is limited. This also implies that peer effects still have significant potential to be unleashed. The mean value of Interpersonal Trust is 2.0670 with a standard deviation of 1.1261, also measured on a 5-point scale. The mean value is slightly higher than that of Peer Effects, indicating that farmers' trust in strangers is at a moderately low level. This is consistent with the characteristics of rural acquaintance societies, but the relatively low interpersonal trust may to a certain extent restrict the cross-group transmission of technical information.

TABLE 3 Basic characteristics of sample farming households.

Characteristic	Option	Frequency	Percentage	Characteristic	Option	Frequency	Percentage
Household head age	18–30 years old	9	1.27	Labor force	0–1 person	26	3.63
	31–45 years old	128	17.87		2–3 people	340	47.48
	46–60 years old	478	66.75		4–5 people	342	47.77
	61 years and above	101	14.11		6 or more people	8	1.12
Educational level	Less than 6 years	238	33.24	Farmland Area	0.67 hectares or less	210	29.33
	6–9 years	387	54.05		0.67–2 hectares	448	62.57
	9–12 years	88	12.29		2–3.33 hectares	45	6.29
	More than 12 years	3	0.42		More than 3.33 hectares	13	1.82

TABLE 4 Descriptive statistics.

Variable	Mean	Standard deviation
Adoption decision	0.2793	0.4490
Adoption intensity	0.1459	0.3028
Peer effects	2.0028	0.9372
Interpersonal trust	2.0670	1.1261
Institutional trust	3.2695	1.1162
Age	52.0852	8.7511
Educational level	7.9860	2.6248
Health status	2.7570	0.5069
Total household income	17.4917	22.1410
Family labor	3.2570	1.0178
Farmland scale	1.0179	0.6832
Crop types	0.8296	0.3762
Agricultural machinery types	0.3715	0.5383
Risk attitude	2.7723	0.9766
Natural disasters	0.6522	0.4766
Difficulty of technology acquisition	3.8617	1.0809
Region	0.4986	0.5003

The standard deviations of the three variables are all within a reasonable range, with no extreme dispersion, indicating that the sample data are relatively stably distributed, laying a reliable data foundation for subsequent empirical analysis.

4.2 The impact of peer effects and social trust on farmers' adoption of water-saving irrigation technology

The influence of peer effects on farmers' adoption of water-saving irrigation technologies is presented in Models (1a), (2b), (5a), and (6b) of Table 5. The results of Model (1a) show that the estimated coefficient of peer effects is 0.14 and is statistically significant at the 1% level,

indicating that peer effects promote the likelihood of farmers adopting water-saving irrigation technologies. The marginal effect reveals that for each one-unit increase in the level of peer effects, the probability of adoption increases by 15%. Similarly, the results of Model (2b) demonstrate that the estimated coefficient of peer effects is 0.09, also significant at the 1% level, suggesting that peer effects enhance the intensity of adoption. Specifically, a one-unit increase in the level of peer effects is associated with a 9.23% increase in the intensity of technology adoption. These findings imply that, in the process of agricultural technology diffusion, peer-driven behavior, grounded in cost minimization and the psychological aversion to social isolation, facilitates learning through observation and imitation. This, in turn, reduces the costs associated with searching for and acquiring information about agricultural technologies and mitigates the perceived risks linked to technological uncertainty. Moreover, widespread peer behavior may intensify farmers' psychological aversion to isolation, further encouraging the adoption of water-saving irrigation technologies. Hypothesis H1 is thus empirically supported.

The impact of social trust on farmers' adoption of water-saving irrigation technology is presented in models (3a), (4b), (5a), and (6b) in Table 5. The results of models (3a) and (4b) show that the estimated coefficient for interpersonal trust is 0.06 and significant at the 1% statistical level, meaning that a higher level of interpersonal trust significantly encourages farmers to adopt water-saving irrigation technology. The marginal effect is that for every unit increase in the level of interpersonal trust, the likelihood of a farmer adopting water-saving irrigation technology increases by approximately 6%. The results of model (4b) indicate that the estimated coefficient for interpersonal trust is 0.05 and significant at the 1% statistical level, meaning that interpersonal trust significantly increases the intensity of adoption among farmers. Specifically, for every unit increase in the level of interpersonal trust, the intensity of adoption increases by 4.46%. Hypothesis 2 (H2) is confirmed. In model (3a), the estimated coefficient for institutional trust is 0.04 and significant at the 1% statistical level, implying that institutional trust has a significant positive effect on farmers' adoption of water-saving irrigation technology, with the marginal effect being that for every unit increase in institutional trust, the probability of adopting water-saving irrigation technology increases by 3.56%. However, institutional trust does not enhance the intensity of adoption. These results imply that a stronger level of interpersonal trust can facilitate cooperation and mutual assistance mechanisms among farmers, enhance information exchange, and improve the adoption behavior of water-saving irrigation technologies. Hypothesis 2 (H2) is again confirmed.

TABLE 5 Regression results of peer effects and social trust on farmers' adoption behavior of water-saving irrigation technology.

Variables	Model (1a)	Model (2b)	Model (3a)	Model (4b)	Model (5a)	Model (6b)
	Adoption decision	Adoption intensity	Adoption decision	Adoption intensity	Adoption decision	Adoption intensity
Peer effects	0.1439*** (0.0121)	0.0923*** (0.0112)			0.1500*** (0.0120)	0.0939*** (0.0115)
Interpersonal trust			0.0600*** (0.0120)	0.0446*** (0.0094)	0.0673*** (0.0127)	0.0297*** (0.0092)
Institutional trust			0.0356*** (0.0132)	0.0138 (0.0094)	0.0322*** (0.0113)	0.0349*** (0.0090)
Difficulty of technology acquisition	0.0731*** (0.0137)	0.0388*** (0.0094)	0.0356*** (0.0132)	0.0138 (0.0094)	0.0610*** (0.0132)	0.0353*** (0.0094)
Age	0.0011 (0.0016)	0.0018 (0.0012)	0.0012 (0.0017)	0.0015 (0.0013)	0.0018 (0.0015)	0.0020* (0.0012)
Educational level	0.0067 (0.0054)	0.0055 (0.0041)	0.0061 (0.0058)	0.0053 (0.0042)	0.0069 (0.0053)	0.0052 (0.0040)
Health status	0.0042 (0.0279)	0.0062 (0.0213)	-0.0095 (0.0306)	-0.0040 (0.0219)	0.0060 (0.0267)	0.0076 (0.0210)
Total household income	0.0008* (0.0005)	0.0011** (0.0005)	0.0014** (0.0005)	0.0014*** (0.0005)	0.0008* (0.0005)	0.0011** (0.0005)
Family labor	-0.0155 (0.0133)	-0.0128 (0.0099)	-0.0099 (0.0141)	-0.0079 (0.0102)	-0.0176 (0.0127)	-0.0125 (0.0098)
Farmland scale	0.1050*** (0.0210)	0.0510*** (0.0165)	0.1290*** (0.0225)	0.0630*** (0.0165)	0.0945*** (0.0195)	0.0480*** (0.0165)
Crop types	-0.1872*** (0.0346)	-0.1667*** (0.0305)	-0.2212*** (0.0367)	-0.1806*** (0.0313)	-0.1698*** (0.0339)	-0.1535*** (0.0301)
Agricultural machinery types	-0.0258 (0.0243)	-0.0184 (0.0193)	-0.0113 (0.0264)	-0.0166 (0.0200)	-0.0295 (0.0233)	-0.0261 (0.0192)
Risk attitude	-0.0207 (0.0135)	-0.0117 (0.0104)	-0.0187 (0.0145)	-0.0098 (0.0107)	-0.0207 (0.0129)	-0.0103 (0.0102)
Natural disasters	-0.0110 (0.0277)	-0.0085 (0.0213)	-0.0340 (0.0300)	-0.0230 (0.0219)	-0.0139 (0.0268)	-0.0120 (0.0210)
Region	0.0731*** (0.0137)	0.0249 (0.0233)	0.0298 (0.0334)	0.0127 (0.0241)	0.1500*** (0.0120)	0.0179 (0.0230)
N	716	716	716	716	716	716
Pseudo R ²	0.3493	0.6082	0.2480	0.4816	0.3645	0.6489

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors. Model codes: "a" denotes regression models with "Adoption Decision" as the dependent variable, and "b" denotes regression models with "Adoption Intensity" as the dependent variable.

The marginal effect reveals that for each one-unit increase in the level of peer effects, the probability of adoption increases by 15%. This effect size is substantively significant when compared to common policy interventions: For example, existing studies show that a 10–20% subsidy for water-saving irrigation equipment typically increases adoption probability by 8–12%, and short-term technical training programs (1–3 days) yield an average promotion effect of 13–17%. The 15% effect of peer effects is comparable to these interventions but offers unique advantages of low cost and sustainable diffusion, unlike subsidies that impose fiscal burdens or training that requires continuous resource input, peer effects rely on spontaneous social interactions among farmers, making them more scalable in resource-constrained regions.

It can be seen from the two forest plots below that: (1) The coefficient of Peer Effects is 0.1500***, and its 95% confidence interval does not cross the 0-axis, which is consistent with Model (5a) in Table 5. This confirms that peer effects exert a significant positive driving effect on adoption decisions, with a marginal effect of 15%. Interpersonal Trust (0.0673***), Institutional Trust (0.0322***) and Difficulty of Technology Acquisition (0.0610***) all have a significant positive impact on adoption decisions, and their coefficients fully match those in Table 5, demonstrating the key role of social trust and technology accessibility. (2) Peer Effects (0.0939***), Interpersonal Trust (0.0297***) and Institutional Trust (0.0349***) still show significant positive effects, but their coefficients are smaller than those in Model (5a). This is consistent with the conclusion in Table 5 that “the

impact of core variables on adoption intensity is weaker than that on adoption decisions". The coefficient of Difficulty of Technology Acquisition is 0.0353***, which is lower than 0.0610 in Model (5a), confirming that "the impact of technology accessibility on 'whether to adopt' is stronger than that on 'the extent of adoption'".

The forest plots visually present the regression results in Table 5, clearly distinguishing the differences in the impact of "adoption decisions" and "adoption intensity": core variables (peer effects, social trust) have a stronger driving effect on decisions, while control variables (age, income) have a more significant impact on intensity. Additionally, the adoption intensity model exhibits better fitting performance, which fully verifies the quantitative conclusions in Table 5 (Figures 2 and 3).

4.3 Endogeneity issues

According to the previous analysis, the model regression may face endogeneity issues. On one hand, there might be omitted variable problems in the chosen explanatory variables, with variables that are difficult to measure accurately (such as farmers' learning ability, infrastructure conditions) potentially influencing both peer effects and farmers' adoption behavior of water-saving irrigation technology. On the other hand, group behavior may cause reflection issues in the process of influencing farmers' adoption of the technology, leading to inconsistent estimated coefficients. To overcome potential endogeneity issues, a two-stage regression was conducted using a combination of the instrumental variable method and conditional mixed process (CMP) estimation. Drawing on the research by Ji and Zhang (2021), "social interaction with other farmers in the village" and "trust levels of other farmers in the village" were used as instrumental variables for peer effects and social trust⁴⁵. The CMP first-stage regression results in Table 6 indicate that social interaction with other farmers in the village significantly positively affects peer effects, while interpersonal trust and institutional trust of other villagers significantly positively affect the interpersonal trust and institutional trust of the sample farmers, meeting the relevance condition of the instrumental variables and not having a direct impact on the adoption behavior of water-saving irrigation technology. Further endogeneity

tests with the parameter *aranhrho_12* passed the significance test, suggesting the presence of endogeneity in the estimation of peer effects, interpersonal trust, and institutional trust. The CMP second-stage estimation results, after correcting for potential endogeneity bias, show that the direction and significance of the impact of peer effects, interpersonal trust, and institutional trust on both adoption decision and the intensity of adoption are consistent with the previous analysis, further validating the robustness of the model.

4.4 Robustness tests

Robustness tests are conducted as follows. First, we employ propensity score matching to estimate the net impact of peer effects on farmers' adoption of water-saving irrigation technologies. Specifically, we categorize farmers with peer effect metrics of 3 or less as the "Weak Peer Effects" group and those above 3 as the "Strong Peer Effects" group. We calculate propensity scores using a logit model and perform matching using three different methods; we then analyze the differences in adoption decisions and intensity between the "Weak" and "Strong" peer effect groups, calculating the average treatment effect. As presented in Table 7, "Strong Peer Effects" increase the probability and intensity of adopting water-saving irrigation technologies by 31.03 and 14.72%, respectively. Second, we conduct robustness checks using sub-samples. Given that the majority of sampled farmers are middle-aged or older, we exclude farmers under 30 years of age from the regression estimates. The results, as shown in Table 8, are largely consistent with the main findings. Overall, the conclusions of the study are relatively robust.

5 Further mechanism analysis

5.1 Interaction analysis of peer effects and social trust on farmers' adoption behavior of water-saving irrigation technology

To further examine the interaction between peer effects and social trust on farmers' adoption behavior of water-saving irrigation

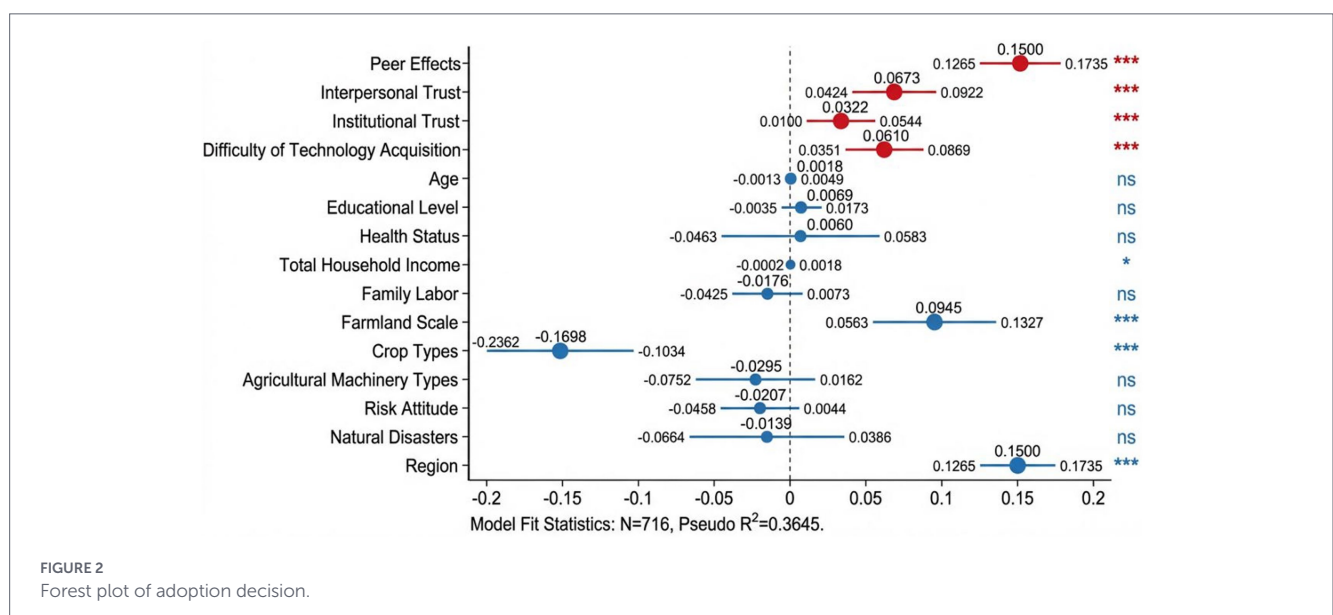


FIGURE 2 Forest plot of adoption decision.

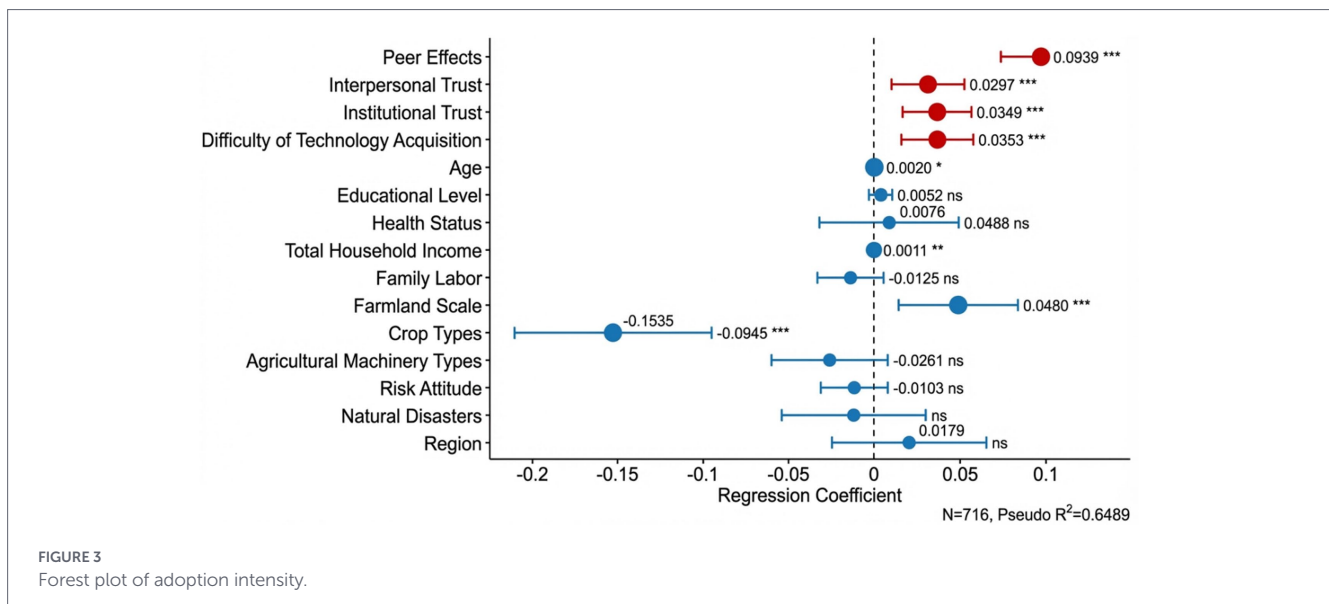


FIGURE 3
Forest plot of adoption intensity.

technology, interaction terms for peer effects and interpersonal trust, as well as institutional trust, were included in the models. The results in Table 9 models (1a) and (2b) show that the coefficient of the interaction term between peer effects and interpersonal trust is 0.17 and significant at the 1% level for whether farmers adopt the technology, but not significant for the intensity of adoption. This indicates a complementary relationship between peer effects and interpersonal trust in influencing whether farmers adopt water-saving irrigation technology. The possible explanation is that peer effects can save information costs and avoid uncertainty risks associated with technology adoption, while a higher level of interpersonal trust can promote cooperative mechanisms among farmers, thereby increasing the likelihood of adoption, but not affecting the intensity of adoption. The regression results for models (3a) and (4b) show that the coefficients of the interaction terms between peer effects and institutional trust are -0.22 and -0.01 , respectively, and significant at the 1 and 5% levels, indicating a substitutive relationship between peer effects and institutional trust in influencing both whether farmers adopt and the intensity of adoption of water-saving irrigation technology. The possible explanation is that both peer effects and institutional trust have roles in saving information costs and avoiding uncertain risks, and they may have homogeneity, which should reinforce each other's influence, but they offset each other in the results, leading to a substitutive relationship. In practice, peer effects enable farmers to learn and understand knowledge and basic operations about water-saving irrigation technology more directly and conveniently, providing a clear proximity advantage. Thus, peer effects and institutional trust produce a substitutive relationship in influencing farmers' adoption behavior of water-saving irrigation technology.

It can be concluded from Figures 4 to 7 that: (1) In Figure 4 (Peer Effects \times Interpersonal Trust – Adoption Decision), there is a significant complementary relationship between the two variables (the interaction term coefficient in Model (1) of Table 9 is 0.1686^{***}). The interaction effect values in the heatmap increase as the levels of both variables rise (from 0.025 to 0.2085), confirming that the synergistic promotional effect on adoption decisions is strongest when “high peer effects + high interpersonal trust” are present. The heatmap visualizes the “ $1 + 1 > 2$ ” logic, interpersonal trust reduces uncertainty in information transmission among peers and strengthens the willingness to imitate behaviors. (2) In Figure 5

(Peer Effects \times Interpersonal Trust – Adoption Intensity), the complementary relationship is not significant (the interaction term coefficient in Model (2) of Table 9 is 0.0125 , non-significant). The effect values in the heatmap (ranging from 0.1013 to 0.6053) show a gentle gradient, with no “double-high enhancement” trend. In Model (2) of Table 9, the main effect of peer effects (0.0546^{**}) is significant, while the main effect of interpersonal trust (0.0038) is weak, and the interaction term is non-significant. This indicates that the two variables only promote “whether to adopt” but hardly affect “the extent of adoption,” as adoption intensity is more dependent on hard conditions such as household resources and technology adaptability. (3) In Figure 6 (Peer Effects \times Institutional Trust – Adoption Decision), there is a significant substitutive relationship between the two variables (the interaction term coefficient in Model (3) of Table 9 is -0.2143^{***}). In the heatmap, under the same level of peer effects, the higher the institutional trust, the lower the effect value (for example, when peer effects are at Level 5, the effect value of the low institutional trust group is 11.6701 , while that of the high institutional trust group is 10.4705). In Model (3) of Table 9, both the main effects of peer effects (1.5030^{***}) and institutional trust (0.7716^{***}) are strong and significant, but the interaction term is negative. This confirms that the two variables are functionally homogeneous (both reduce information costs) and exhibit a “one strengthens while the other weakens” pattern, when institutional trust provides policy guarantees, farmers' reliance on peers' behaviors decreases. (4) In Figure 7 (Peer Effects \times Institutional Trust – Adoption Intensity), a significant substitutive relationship exists, but its strength is weaker than that in the adoption decision dimension (the interaction term coefficient in Model (4) of Table 9 is -0.0118^{**}). The effect values in the heatmap show a gentle gradient, but the trend is clear: the promotion of peer effects is more obvious in the low institutional trust group (increasing from 0.0603 to 0.1361), while the promotion is limited in the high institutional trust group (increasing from 0.0363 to 0.0884). In Model (4) of Table 9, the main effect of peer effects (0.1363^{***}) still dominates, the main effect of institutional trust (0.0441^{***}) is weak, and the interaction term is significantly negative. This indicates that in terms of adoption intensity, institutional trust also acts as a substitute for peer effects, but peer experience remains crucial.

TABLE 6 Endogeneity test results.

Variables	Peer effects	Interpersonal trust	Institutional trust	Adoption decision			Adoption intensity		
	First stage	First stage	First stage	Second stage			Second stage		
Peer effects				1.3193*** (0.0439)			0.2431*** (0.0673)		
Interpersonal trust					0.5800*** (0.1122)			0.1093*** (0.0300)	
Institutional trust						0.8072*** (0.0868)			0.1856 (0.0848)
Villagers' social interaction	0.1943*** (0.0382)								
Villagers' interpersonal trust		0.6118*** (0.0675)							
Villagers' institutional trust			0.2989*** (0.0811)						
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Aranhrho_12				-1.6134*** (0.2735)	-0.4637** (0.1660)	-1.1798*** (0.3275)	-0.4924* (0.1999)	-0.2795* (0.1164)	-0.6627* (0.2739)
LR chi2				264.73	296.56	239.68	218.65	250.65	188.21

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors.

TABLE 7 Robustness test – estimated impact of different intensities of peer effects on farmers' adoption behavior of water-saving irrigation.

Variables	Matching method	Average treatment effect	T-test	Mean
Adoption decision	K-nearest neighbor matching	0.3060*** (0.0522)	6.62	0.3103
	Caliper matching	0.3265*** (0.0465)	7.43	
	Kernel matching	0.2985*** (0.0378)	6.87	
Adoption intensity	K-nearest neighbor matching	0.1336*** (0.0390)	3.91	0.1472
	Caliper matching	0.1671*** (0.0404)	5.19	
	Kernel matching	0.1408*** (0.0331)	4.40	

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors.

This substitutive relationship between peer effects and institutional trust carries profound theoretical and policy implications. Theoretically, it stems from their functional homogeneity in reducing transaction costs and perceived uncertainty (aligned with transaction cost theory). Specifically, peers lower information asymmetry through close-range interactions, such as on-site demonstrations of irrigation operations, sharing of real cost–benefit data, and mutual validation of adoption effects, thereby mitigating farmers' risk aversion toward unfamiliar

technologies. Institutions, by contrast, achieve similar goals through authoritative policy endorsements, standardized technical training, and subsidy guarantees that reduce financial constraints. From the perspective of the theory of planned behavior, peer effects shape farmers' subjective norms (perceiving “most neighbors adopting” as a social norm), while institutional trust enhances their perceived behavioral control (believing “government-supported technologies are reliable and accessible”). When one of these psychological drivers is sufficiently strong,

TABLE 8 Robustness test – impact of peer effects and social trust on water-saving irrigation technology adoption behavior in a sub-sample.

Variables	Model (1a)	Model (2b)	Model (3a)	Model (4b)	Model (5a)	Model (6b)
	Adoption decision	Adoption intensity	Adoption decision	Adoption intensity	Adoption decision	Adoption intensity
Peer effects	0.1529*** (0.0136)	0.1135*** (0.0133)			0.1549*** (0.0137)	0.1138*** (0.0135)
Interpersonal trust			0.0665*** (0.0144)	0.0492*** (0.0116)	0.0375*** (0.0131)	0.0376*** (0.0109)
Institutional trust			0.0303* (0.0159)	0.0080 (0.0116)	0.0619*** (0.0151)	0.0270** (0.0111)
Difficulty of technology acquisition	0.0542*** (0.0163)	0.0350*** (0.0117)	0.0792*** (0.0185)	0.0448*** (0.0123)	0.0412*** (0.0159)	0.0302*** (0.0116)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
N	716	716	716	716	716	716
Pseudo R ²	0.3493	0.6082	0.2480	0.4816	0.3645	0.6489

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors. Model codes: “a” denotes regression models with “Adoption Decision” as the dependent variable, and “b” denotes regression models with “Adoption Intensity” as the dependent variable.

TABLE 9 Regression results of the interaction between peer effects and social trust.

Variables	Model (1a)	Model (2b)	Model (3a)	Model (4b)
Adoption	Adoption intensity	Adoption decision	Adoption intensity	Adoption decision
Peer effects	0.2659* (0.1502)	0.0546** (0.0239)	1.5030*** (0.2305)	0.1363*** (0.0204)
Interpersonal trust	0.0277 (0.1589)	0.0038 (0.0209)		
Peer effects × Interpersonal trust	0.1686*** (0.0613)	0.0125 (0.0084)		
Institutional trust			0.7716*** (0.1600)	0.0441*** (0.0124)
Peer effects × Institutional trust			-0.2143*** (0.0622)	-0.0118** (0.0054)
Control variables	Controlled	Controlled	Controlled	Controlled
N	716	716	716	716
Pseudo R ²	0.3649	0.6503	0.3998	0.6446

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors. Model codes: “a” denotes regression models with “Adoption Decision” as the dependent variable, and “b” denotes regression models with “Adoption Intensity” as the dependent variable.

the marginal contribution of the other diminishes, leading to the observed substitutive relationship. Policy-wise, this finding implies a “context-dependent” strategy: In communities with low institutional trust (e.g., remote rural areas where policy implementation is weak or farmers hold skeptical attitudes toward government propaganda), peer networks become the primary channel for technology diffusion, effectively filling the gap in institutional support. Conversely, in regions with strong institutional trust (e.g., suburban areas with well-established agricultural extension systems and effective subsidy policies), farmers can obtain comprehensive information and reliable support through official channels, thus reducing their reliance on peer recommendations. This suggests that policymakers should avoid a “one-size-fits-all” approach and instead flexibly adjust the focus of promotion efforts based on local institutional trust levels.

5.2 Mediating role analysis of the difficulty of technology acquisition

Lastly, an examination was conducted to verify whether peer effects and social trust can influence farmers’ adoption behavior of water-saving irrigation technology through the mediating role of the difficulty of technology acquisition. This was discussed along three pathways: “Peer Effects → Difficulty of Technology Acquisition → Farmers’ Adoption Behavior of Water-Saving Irrigation Technology,” “Interpersonal Trust → Difficulty of Technology Acquisition → Farmers’ Adoption Behavior of Water-Saving Irrigation Technology,” and “Institutional Trust → Difficulty of Technology Acquisition → Farmers’ Adoption Behavior of

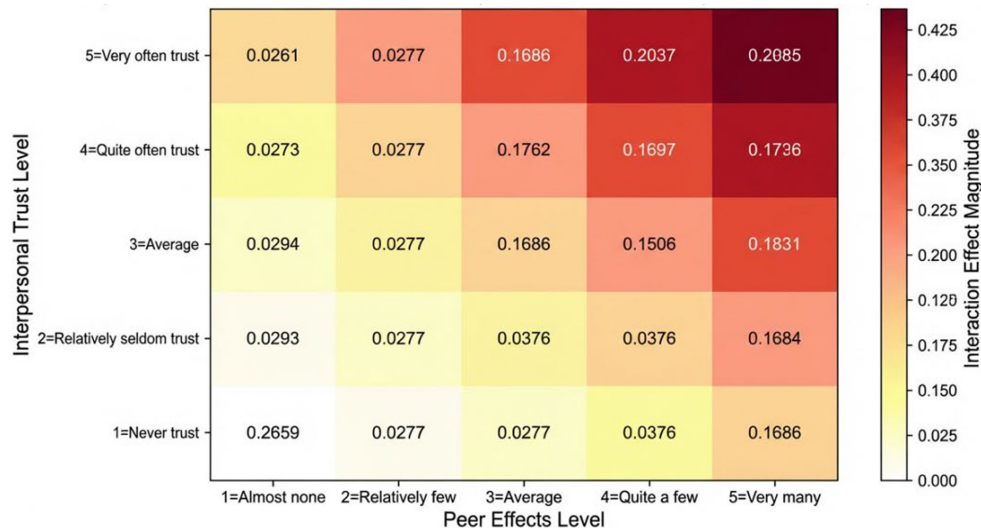


FIGURE 4 Interaction heatmap of peer effects * interpersonal trust on adoption decision.

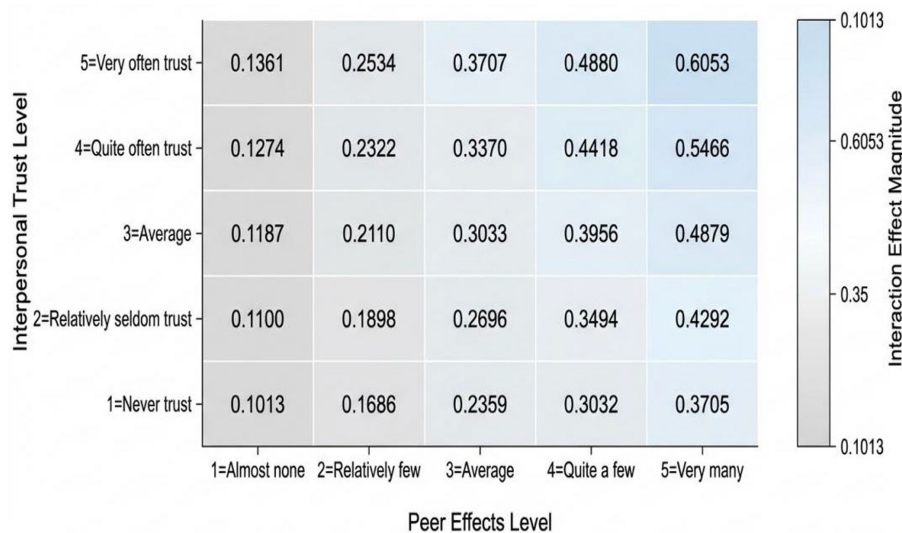


FIGURE 5 Interaction heatmap of peer effects * interpersonal trust on adoption intensity.

Water-Saving Irrigation Technology.”The analysis results are presented in Table 10 and Figure 8.

A “Peer Effects → Difficulty of Technology Acquisition → Farmers’ Adoption Behavior of Water-Saving Irrigation Technology.” The results in Table 10, model (1), show that the estimated coefficient for peer effects is 0.17 and significant at the 1% statistical level, indicating that peer effects reduce the difficulty of technology acquisition for farmers; in model (2), the estimated coefficient for the difficulty of technology acquisition is 0.08 and also significant at the 1% statistical level, suggesting that for every unit increase in the ease of technology acquisition, the probability of farmers adopting water-saving irrigation technology increases by 7.31%; furthermore, the bootstrap confidence interval does not include 0, confirming the mediation effect, which means

that peer effects enhance the likelihood of farmers adopting water-saving irrigation technology by lessening the difficulty of technology acquisition. The estimated coefficient for the difficulty of technology acquisition in model (3) is 0.04 and significant at the 1% statistical level, meaning that for every unit increase in ease of technology acquisition, the intensity of adoption of water-saving irrigation technology increases by 3.88%; again, as the bootstrap confidence interval does not include 0, the mediation effect holds, indicating that peer effects elevate the intensity of adoption of water-saving irrigation technology by lowering the difficulty of technology acquisition. The significance of these results lies in the fact that peer effects, by diminishing the challenge farmers face in learning about or acquiring water-saving irrigation technology and by strengthening the exchange of technical information within groups, enhance the efficiency of technology dissemination,



FIGURE 6 Interaction heatmap of peer effects * institutional trust on adoption decision.

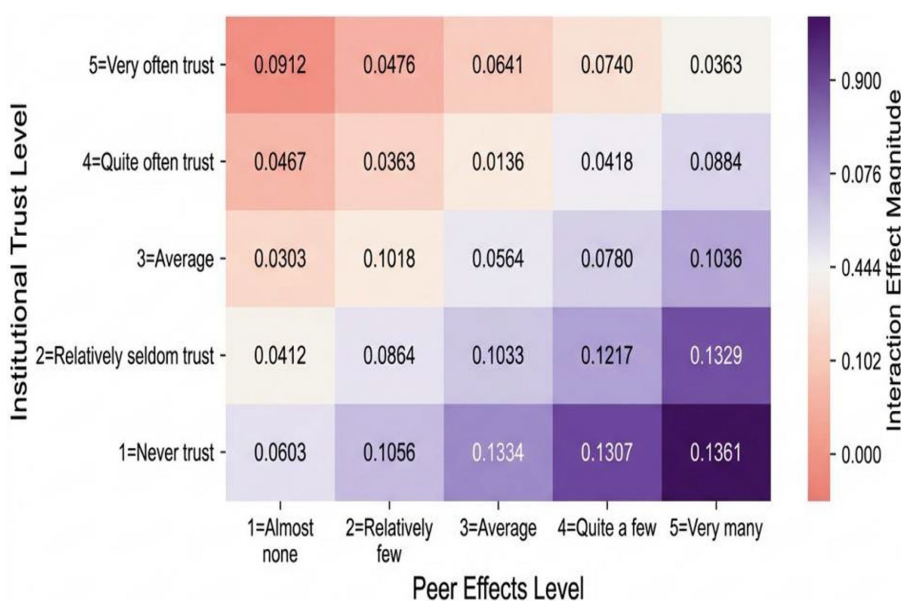


FIGURE 7 Interaction heatmap of peer effects * institutional trust on adoption intensity.

break down information constraints, and increase both the likelihood and extent of adoption. This, in turn, is conducive to agricultural water-use efficiency and water resource conservation.

B “Interpersonal Trust → Difficulty of Technology Acquisition → Farmers’ Adoption Behavior of Water-Saving Irrigation Technology.” The results for Table 10, model (5), show an estimated coefficient for interpersonal trust of -0.0027 , which is not significant, indicating that interpersonal trust does not impact the difficulty of technology acquisition; in models (5) and (6), the estimated coefficients for the difficulty of technology acquisition are 0.10 and 0.05, respectively, both significant at the 1% statistical level. This implies that for every unit decrease in difficulty of technology acquisition, the

probability and intensity of adoption of water-saving irrigation technology, respectively, increase by 10.07 and 4.99%; however, since the bootstrap confidence intervals include 0, the mediation effect is not established.

C “Institutional Trust → Difficulty of Technology Acquisition → Farmers’ Adoption Behavior of Water-Saving Irrigation Technology.” In Table 10, model (7), the estimated coefficient for institutional trust is 0.11 and significant at the 1% statistical level, indicating that institutional trust reduces the difficulty of technology acquisition for farmers; in model (2), the estimated coefficient for the difficulty of technology acquisition is 1,005 and significant at the 1% statistical level, suggesting that for every unit increase in ease of technology acquisition, the probability of farmers adopting

water-saving irrigation technology increases by 10.05%; as the bootstrap confidence interval does not include 0, the mediation effect is confirmed. The estimated coefficient for the difficulty of technology acquisition in model (3) is 0.05 and significant at the 1% statistical level, meaning that for every unit increase in ease of technology acquisition, the intensity of adoption of water-saving irrigation technology increases by 7.88%; again, as the bootstrap confidence interval does not include 0, the mediation effect holds, indicating that institutional trust enhances the intensity of adoption of water-saving irrigation technology by lowering the difficulty of technology acquisition. The significance of these results lies in the role of institutional trust in promoting farmers' adoption behavior of water-saving irrigation technology by broadening their radius for information exchange and improving their information acquisition capabilities, thereby strengthening the interaction between farmers and government.

6 Discussion and implications

The adoption of water-saving irrigation technologies by farmers is not only a significant driver of sustainable agricultural development but also a complex individual decision-making process influenced by external social environmental factors such as peer effects and social trust. The dissemination of information related to water-saving irrigation technologies is a crucial prerequisite for farmers' adoption decisions. This process relies not only on government policy-driven hard channels but also on soft channels driven by other farmers' group behavior effects, forming an indispensable consideration in the adoption process of water-saving irrigation technologies. The empirical analysis of the influence of peer effects and social trust on farmers' adoption of water-saving irrigation technologies in this study provides insights that help understand the role of social factors in this context. Given that the reliability and nature of technology information transmitted by peer effects and institutional trust differ, their substitutability has distinctly different implications for farmers' decision-making in adopting water-saving irrigation technologies. For instance, the information transmission within peer effects may drastically influence farmers' decisions regarding water-saving irrigation technologies, intensifying the "following the herd" mentality due to the psychological belief of being in the minority. On the other hand, institutional trust can provide accurate and reliable information, which is comparatively more helpful in alleviating information asymmetry issues. The impact of different social factors on farmers' adoption of water-saving irrigation technologies also varies across groups.

(1) Dialogue with Existing Studies. To further contextualize the findings, this study compares its results with those of similar studies in the field, exploring consistencies, contradictions, and underlying reasons:

a Consistency with existing research

First, regarding the main effect of peer effects, this study finds that peer effects significantly increase farmers' adoption probability

by 15% and adoption intensity by 9.23%, which aligns with the core conclusions of most agricultural technology adoption studies. For example, Di Falco et al. (2020) found that peer effects promote smallholder farmers' adoption of climate adaptation technologies by reducing information search costs (Wang and Luo, 2024), with a marginal effect of approximately 12%; Meng et al. (2023) confirmed that peer behavior imitation increases the probability of biogas adoption among rural households by 14.2% (Zhou et al., 2008). The consistency verifies that peer effects, as a key social diffusion mechanism, play a stable role in agricultural technology promotion, whether for food crops or cash crops (e.g., watermelons), farmers tend to reduce decision-making risks through observing peers' behaviors, which is rooted in the bounded rationality of agricultural producers and the characteristics of rural acquaintance societies. Second, the positive impact of social trust on technology adoption is consistent with existing literature. Tao et al. (2022) found that interpersonal trust increases farmers' organic fertilizer substitution behavior by 8.3% by strengthening cooperative mechanisms; Yuan et al. (2022) emphasized that institutional trust enhances policy implementation efficiency, thereby promoting the adoption of public welfare agricultural technologies. This study supplements that interpersonal trust affects both adoption probability and intensity, while institutional trust only influences adoption probability, this nuance further enriches the understanding of trust's heterogeneous effects, but the core conclusion that "trust reduces information asymmetry and transaction costs" is consistent with the theoretical framework of social embeddedness theory (Prager and Posthumus, 2010).

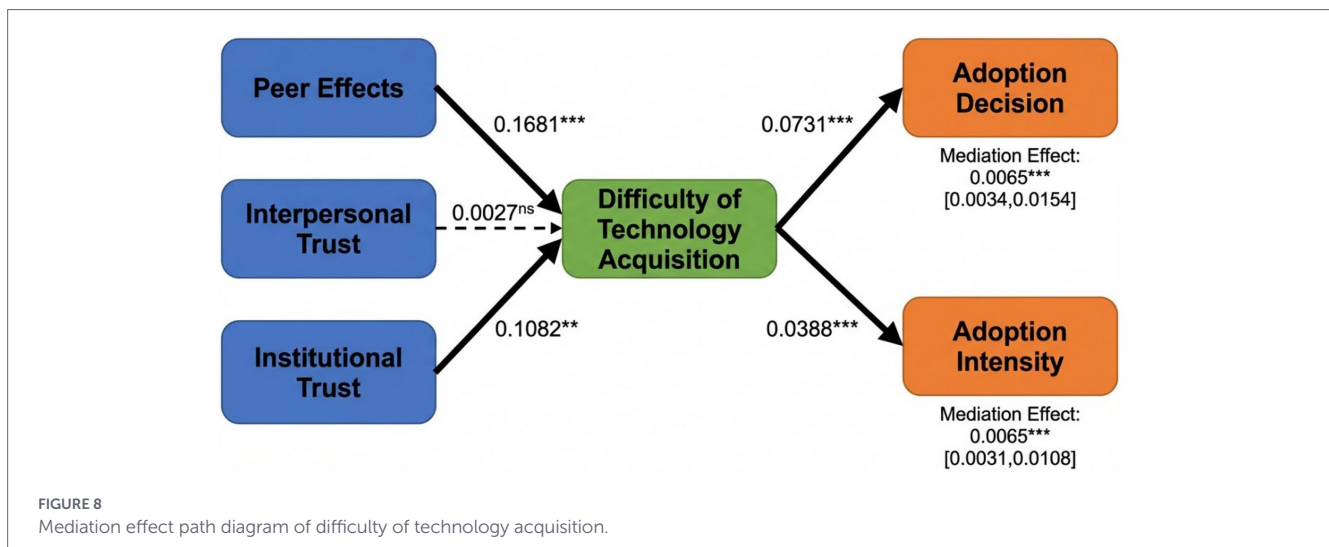
b Contradictions and explanations

The most notable difference from existing studies lies in the interactive relationship between peer effects and institutional trust. Most previous studies have assumed a complementary relationship between the two, for example, Amadu (2023) argued that institutional support (e.g., government training) can enhance the credibility of peer information, thereby amplifying peer effects; Skevas et al. (2022) found that policy subsidies and peer recommendations jointly promote the adoption of unmanned aerial vehicles. However, this study confirms a substitutive relationship: when institutional trust is high, the marginal effect of peer effects decreases by 0.2143 (Table 8). The key reason for this contradiction is the heterogeneity of research objects and technology types: Most existing studies focus on grain crops (e.g., rice, wheat) with low water demand and mature irrigation technologies, where government subsidies and technical training can directly reduce adoption costs, thus complementing peer information dissemination. This study targets watermelon growers in water-scarce regions. Watermelon has high water demand and strict requirements for irrigation efficiency, and farmers' core concerns are practical operational issues (e.g., equipment maintenance, water-saving effect verification) rather than financial constraints. Peer effects provide on-site demonstration and experience sharing that official channels cannot easily match, while institutional trust mainly solves policy credibility issues. When farmers trust government policies, they still rely on peers for operational guidance, but the "information gap" narrowed by institutions reduces their dependence on peer behavior imitation, leading to a substitutive relationship. Another minor difference is the mediating role of

TABLE 10 Regression results of the mediating role of difficulty in technology acquisition.

Variables	(1) Difficulty of technology acquisition	(2) Adoption decision	(3) Adoption intensity	(4) Difficulty of technology acquisition	(5) Adoption decision	(6) Adoption intensity	(7) Difficulty of technology acquisition	(8) Adoption decision	(9) Adoption intensity
Peer effects	0.1681*** (0.0444)	0.1438*** (0.0121)	0.0923*** (0.0113)						
Interpersonal trust				0.0027 (0.0363)	0.0549*** (0.0120)	0.0427*** (0.0093)			
Institutional trust							0.1082** (0.0360)	0.0252* (0.0132)	0.0076 (0.0094)
Difficulty of technology acquisition		0.0731*** (0.0137)	0.0388*** (0.0094)		0.1007*** (0.0149)	0.0499*** (0.0097)		0.1005*** (0.0152)	0.0488*** (0.0098)
Mediation effect	0.0065*** (0.0018)			0.0002 (0.0027)			0.0091** (0.0035)		
Adoption decision	[0.0034, 0.0154]			[-0.0066, 0.0040]			[0.0021, 0.0172]		
Mediation effect	0.0065*** (0.0021)			0.0001 (0.0021)			0.0052* (0.0022)		
Adoption intensity	[0.0031, 0.0108]			[-0.0025, 0.0031]			[0.0026, 0.0095]		
N	716	716	716	716	716	716	716	716	716
R or Pseudo R ²	0.0519	0.3493	0.6082	0.0326	0.2470	0.4816	0.0448	0.2280	0.4228

*, **, and *** indicate significance at the 10, 5, and 1% levels, respectively. The numbers in parentheses are standard errors.



technology acquisition difficulty. Ji and Zhang (2021) found that interpersonal trust reduces technology acquisition difficulty by promoting information sharing, but this study does not support this mediation path. The reason may be the measurement dimension of interpersonal trust: Ji and Zhang (2021) measured trust among relatives and neighbors (strong ties), while this study focuses on trust in strangers (weak ties). In rural areas, strong ties dominate information transmission, interpersonal trust among acquaintances mainly affects cooperative behaviors (e.g., joint purchase of equipment) rather than technology information acquisition, thus failing to trigger the mediation effect of acquisition difficulty.

c Theoretical and practical contributions

This study's findings supplement three research gaps in existing literature: First, it verifies the stability of peer effects and social trust in cash crop technology adoption, expanding the application scope of social diffusion theory from grain crops to high-value cash crops. Second, it reveals the substitutive relationship between peer effects and institutional trust, correcting the one-sided assumption of "complementarity" in previous studies and providing a more nuanced analytical framework for policy design. Third, it clarifies the heterogeneous mediating paths of technology acquisition difficulty, highlighting the importance of trust measurement dimensions in empirical research.

(2) Policy Implications. Based on these findings and discussion, the study offers the following policy implications:

(1) Exploiting Complementary Relationships for the Construction of a Dual-Drive Extension Model Featuring Farmer Demonstration and Trust Enhancement. To fully harness the complementary effect between interpersonal trust and peer effects, a "1 + N" demonstration-driven initiative ought to be rolled out under the guidance of agricultural technology extension departments at the county and township levels. First, select core demonstration farmers. Five to eight core demonstration farmers should be chosen per village, prioritizing those with large farmland areas, high technology acceptance, and a sound reputation

among neighbors. These model farmers will be provided with incentives including free technical training and equipment rental subsidies. They are required to organize field workshops on a monthly basis to conduct on-site demonstrations of operational procedures for technologies such as drip irrigation and sprinkler irrigation, and share authentic data on cost recovery cycles and water-saving and yield-increasing effects. Second, establish technical mutual-aid groups. Village collectives should take the lead in setting up technical mutual-aid groups, assigning 3–5 ordinary farmers to each demonstration farmer for "one-on-one guidance and collaborative problem-solving" support activities, thereby strengthening interpersonal trust among farmers. For example, in the survey regions such as Yanliang (Shaanxi Province) and Yanhu District (Shanxi Province), one village collective liaison officer can be designated per village to form a promotion unit characterized by demonstration farmer mentoring + liaison officer coordination. This model not only leverages the information dissemination advantages of peer effects but also consolidates interpersonal trust through organized activities, amplifying the complementary effect of the two factors. Third, implement a trust points system. A trust points system should be introduced in accordance with village regulations. Farmers can accumulate points by participating in mutual-aid activities and sharing technical experience, which can be redeemed for agricultural technical services or production materials, further consolidating the trust-based cooperation network among farmers.

(2) Utilizing Substitutive Relationships to Implement a Differentiated Channel Combination Strategy. Based on the substitutive effect between peer effects and institutional trust, the focus of extension efforts should be flexibly adjusted according to the level of institutional trust across different regions. First, in regions with high institutional trust (such as towns with robust policy enforcement and well-established agricultural technology extension networks), priority should be given to strengthening official policy support and technical guarantees. The government should issue relevant policies specifying subsidy

ratios for equipment purchase and standards for installation subsidies; establish a “one village, one agricultural technician” assignment system, deploying one full-time agricultural technician to each village to provide free on-site installation guidance and regular equipment maintenance services, thereby reducing farmers’ reliance on peer-sourced information. Second, in remote villages with weak institutional trust but frequent neighborhood interactions, peer-based promotion should be prioritized. Organize demonstration farmer lecture tours, where model farmers explain technological advantages in local dialects; produce short videos featuring farmers sharing their experiences and disseminate them via village-level WeChat groups to lower the threshold for farmers to adopt the technologies. Third, for large-scale farmers, provide combined support of policy subsidies + peer technical exchange. Subsidy policies grounded in institutional trust address farmers’ financial concerns, while peer effects resolve practical operational difficulties, giving full play to the substitutive advantages of these two channels.

- (3) Synergizing Mediating Effects to Construct a “Trust→Information→Technology” Trinity Support System. In combination with the mediating role of technology acquisition difficulty, optimize information transmission and technical services to smooth the transmission pathway of “trust → reducing technology acquisition difficulty → promoting technology adoption.” First, rely on peer trust networks. Build village-level technical information sharing platforms operated by demonstration farmers to share real-time practical information such as equipment maintenance tips and key pest control measures, reducing farmers’ information search costs. Second, strengthen technical service guarantees through institutional trust. The government, in collaboration with agricultural technology extension institutions, should compile relevant materials such as the Simplified Manual for Water-Saving Irrigation Technology, which decomposes the entire process of installation, operation, and maintenance with illustrations and texts; set up equipment display and experience centers at township agricultural technology stations; and provide both online and offline technical services to promptly respond to farmers’ inquiries. Third, establish a two-tier service mechanism. Address the pain points reported by farmers (such as complicated operation and inconvenient maintenance) through a two-tier service mechanism of preliminary troubleshooting by demonstration farmers + professional maintenance by agricultural technicians. This mechanism not only enables rapid response to demands based on interpersonal trust but also ensures service quality through institutional trust, effectively reducing the difficulty of technology acquisition for farmers.

7 Conclusion

Against the backdrop of climate change and the imperative for sustainable agricultural development, this study investigates the

factors influencing farmers’ adoption behavior of water-saving irrigation technologies. Specifically, it explicates the influence mechanisms of peer effects and social trust on said adoption behaviors. Utilizing survey data from 716 households specializing in fruit cultivation in Xi’an, Shaanxi Province, and Yuncheng, Shanxi Province, the study arrives at the following conclusions: (1) Peer effects significantly encourage farmers’ adoption of water-saving irrigation technologies, with each unit increase in peer effects raising the probability and intensity of technology adoption by 15 and 9.23%, respectively. (2) The level of interpersonal trust within the realm of social trust significantly promotes farmers’ adoption of water-saving irrigation technologies, with each unit increase in interpersonal trust level elevating the likelihood and intensity of technology adoption by approximately 6 and 4.46%, respectively. Institutional trust significantly enhances the probability of farmers adopting water-saving irrigation technologies by 3.56% per unit increase in trust. However, institutional trust does not impact the intensity of adoption of water-saving irrigation technologies by farmers. (3) Peer effects and interpersonal trust demonstrate a complementary relationship in influencing whether farmers adopt water-saving irrigation technologies, whereas peer effects and institutional trust exhibit a substitutive relationship in affecting both the adoption decision and the extent of adoption. (4) Both peer effects and institutional trust enhance farmers’ behavior toward adopting water-saving irrigation technologies by reducing the difficulty in acquiring technology.

8 Limitations

This study has several limitations that should be acknowledged. First, the cross-sectional data collected in 2019–2020 limit the identification of causal relationships, as it cannot capture dynamic changes in peer networks, social trust, or adoption behavior over time. Second, core variables such as peer effects and social trust rely on farmers’ self-reports, which may introduce subjective bias. Third, the sample is restricted to watermelon growers in the Yellow River Irrigation Region of Shaanxi and Shanxi provinces, and the conclusions may not be generalized to other regions with different hydroclimatic conditions, crop types, or institutional environments. Fourth, while the study focuses on “difficulty of technology acquisition” as a mediation pathway, other potential mechanisms (e.g., risk perception reduction, social norm formation) are not explored, leaving room for deeper mechanism analysis. Future research could adopt longitudinal tracking or randomized controlled trials (RCTs) to better identify causal effects, expand the sample to include other crops and regions, and explore additional mediating or moderating variables to enrich the theoretical framework.

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/s.

Author contributions

XD: Writing – original draft, Formal analysis, Methodology, Data curation, Investigation, Conceptualization, Writing – review & editing, Software. HG: Validation, Project administration, Writing – review & editing, Supervision, Funding acquisition, Data curation, Visualization. YQ: Visualization, Resources, Validation, Project administration, Methodology, Writing – review & editing, Funding acquisition. LL: Writing – review & editing, Writing – original draft. KS: Validation, Data curation, Writing – review & editing, Resources, Supervision, Project administration, Visualization.

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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.

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Appendix A: Construction of key variables

To clarify the measurement details of core variables and improve the reproducibility of the study, this appendix provides a systematic summary of the construction of key variables (peer effects, social trust, and other core indicators) through specific question settings, scales, and assignment rules. The detailed information is shown in the attached [Table A1](#).

TABLE A1 Construction of key variables (peer effects, social trust, and other core indicators).

Variable category	Variable name	Specific question settings	Scale/Assignment rules
Core explanatory variables	Peer effects	“How many other farmers in your village have adopted water-saving irrigation technologies?”	5-point Likert scale: 1 = Almost none; 2 = Relatively few; 3 = Average; 4 = Quite a few; 5 = Very many
	Interpersonal trust	“What is your level of trust in strangers?”	5-point Likert scale: 1 = Never trust; 2 = Relatively seldom trust; 3 = Average; 4 = Quite often trust; 5 = Very often trust
	Institutional trust	“What is your level of trust in the government’s policies and publicity regarding water-saving irrigation technologies?”	5-point Likert scale: 1 = Never trust; 2 = Relatively seldom trust; 3 = Average; 4 = Quite often trust; 5 = Very often trust
Dependent variables	Adoption decision	“Have you adopted water-saving irrigation technologies (such as drip irrigation, sprinkler irrigation)?”	Binary variable: 1 = Adopted; 0 = Not adopted
	Adoption intensity	“What is the proportion of your household’s total cultivated land area covered by water-saving irrigation technologies?”	Continuous variable (percentage, e.g., 30% = 0.3)
Mediating variable	Difficulty of technology acquisition	“How difficult is it for you to obtain relevant information about water-saving irrigation technologies and perform practical operations?”	5-point Likert scale: 1 = Very difficult; 2 = Relatively difficult; 3 = Average; 4 = Quite easy; 5 = Very easy