



OPEN ACCESS

EDITED BY

Siyabusa Mkuhlani,
International Institute of Tropical Agriculture
(IITA), Kenya

REVIEWED BY

Inoussa ZAGRE,
Université des Sciences, des Techniques et
des Technologies de Bamako, Mali
Alfred Tunyire Apio,
University of Pretoria, South Africa

*CORRESPONDENCE

Xiuling Ding
✉ dxl7482@gsupl.edu.cn

RECEIVED 14 April 2025

ACCEPTED 25 August 2025

PUBLISHED 18 September 2025

CITATION

Ding X, Li L, Lu Q and Zhang W (2025) Impact of meteorological disaster shocks and collective action on farmers' adoption of soil and water conservation technologies: evidence from the Loess Plateau, China. *Front. Sustain. Food Syst.* 9:1611347. doi: 10.3389/fsufs.2025.1611347

COPYRIGHT

© 2025 Ding, Li, Lu and Zhang. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Impact of meteorological disaster shocks and collective action on farmers' adoption of soil and water conservation technologies: evidence from the Loess Plateau, China

Xiuling Ding^{1*}, Lipeng Li², Qian Lu³ and Weiping Zhang¹

¹College of Economics, Gansu University of Political science and Law, Lanzhou, China, ²School of Economics and Management, Ningxia University, Yinchuan, China, ³College of Economics and Management, Northwest A&F University, Xianyang, China

Introduction: Highlighting the importance of addressing the meteorological disaster shocks (MDS) experiences of potential adopters, alleviating disaster-induced anxiety, and harnessing risk aversion psychology, along with promoting the essence of collective action, can be crucial in facilitating the adoption of soil and water conservation technologies (SWCT).

Methods: This study delves into the intricate dynamics governing the adoption of SWCT among grain growers. This study draws on field survey data from 1,106 farming households across three provinces. Using a binary Probit model and mediation effect analysis, it explores how MDS and collective action influence farmers' adoption of SWCT.

Results: The results reveal several key findings. First, MDS significantly and positively affect farmers' adoption of different types of SWCT. Second, collective action also has a significant positive impact on SWCT adoption. Third, collective action mediates the relationship between MDS and SWCT adoption, indicating that part of MDS's influence is transmitted through collective action. Finally, heterogeneity analysis shows that the impact of MDS on SWCT adoption varies significantly across farmer subgroups defined by age, education level, and planting scale. Likewise, government subsidies, total household land management area, and the number of household agricultural machinery significantly affect farmers' decisions to adopt SWCT.

Discussion and suggestions: Based on the research, the following suggestions are put forward: promote adaptive technologies and strengthen demonstrations and guidance; improve meteorological early warning, establish a disaster case database, and subsidize disaster-stricken farmers; support cooperatives in participating in technology promotion and reward excellent organizations; for farmers aged 55 and below with low educational levels, promote simple technologies, strengthen training, increase subsidies, and drive adoption through demonstrations; optimize subsidy policies, allocate technologies based on resources, and establish an evaluation mechanism for dynamic policy adjustment.

KEYWORDS

meteorological disaster shocks, collective action, soil and water conservation technology, mediation effect, heterogeneity analysis

Introduction

The impacts of climate change are increasingly intensifying, characterized by rising temperatures, erratic rainfall patterns, and increasingly frequent extreme weather events, which have significantly heightened the vulnerability of agricultural systems (Parry, 2019). These vulnerabilities, in turn, have introduced substantial uncertainty into farmers' incomes and exerted direct and indirect influences on long-term national food security and broader social and economic development agendas (Thornton et al., 2014). In mitigating such negative impacts, soil and water conservation technologies (SWTC) have emerged as a crucial solution. SWTC mainly fall into three categories: engineering technologies (such as terrace drainage, contour planting, and fish-scale planting) (Fontes, 2020; Li et al., 2021), biological technologies (such as shelterbelt construction and grass planting), and tillage technologies (such as no-tillage, reduced tillage, and straw mulching) (Jia and Lu, 2018; Huang et al., 2019). They play roles in conserving soil and water, improving rainfall infiltration and soil structure, increasing soil organic matter content, reducing soil erosion, enhancing land productivity, and improving the ecological environment (Kpadonou et al., 2017), thus ensuring farmers' incomes. Meanwhile, they are regarded as important components in achieving the United Nations Sustainable Development Goals, capable of delivering triple benefits—economic, ecological, and social (Altobelli et al., 2020; Ojo et al., 2021)—and serving as effective technologies for resisting disaster risks (Ostrom et al., 1979).

By 2020, over 35% of countries worldwide had promoted and adopted SWTC, covering 11% of the world's arable land. For example, more than 60% of arable land in countries like the United States and Canada had adopted such technologies (Cui et al., 2023). Since the 1940s, the Chinese government has implemented a series of incentive policies and measures to encourage farmers to adopt SWTC, and the application level of various technologies has made certain progress. By 2020, China had built 376,800 hectares of basic farmland using engineering measures, created 1,410,900 hectares of soil and water conservation forests and planted 398,300 hectares of grass using biological measures (Hu et al., 2023; Lei et al., 2023), with soil conservation tillage measures implemented on 1,461,700 hectares of land. However, it should be emphasized that there are many problems in the promotion and application of SWTC. the adoption level of some SWTC is far lower than the international level, especially in the ecologically fragile Loess Plateau region of China (Cao et al., 2017; Jiang et al., 2019; Zhang et al., 2023). farmers, as implementers and beneficiaries of SWTC adoption, have low enthusiasm for active adoption and a relatively low continuous adoption rate, making it difficult for these technologies to effectively mitigate the negative impacts of climate change and MDS (Lingling et al., 2014; Jia and Lu, 2019; Gu et al., 2021; Chen et al., 2023). Therefore, in-depth research and analysis of the determinants influencing farmers' adoption behavior of SWTC are of great significance for formulating effective measures to promote farmers' adoption of such technologies.

In exploring how to encourage farmers to actively adopt SWTC, the academic community has conducted in-depth discussions mainly from two aspects: internal factors and external environment

(Teshome et al., 2016; Jia and Lu, 2019). Regarding internal factors, relevant studies have found that household head characteristics (such as gender, age, and education level) and household endowment characteristics (such as social capital, human capital, agricultural income, and land management area) significantly affect farmers' adoption of SWTC (Wei C. et al., 2022; Wang et al., 2023). In terms of the external environment, some scholars have focused on analyzing the external environmental factors of implementers and found that land property rights, government support (technology promotion, technical training, and subsidies), and regional economic development level all influence farmers' adoption of SWTC (Danso-Abbeam, 2022; Wang Y. et al., 2022). It is worth noting that existing studies have analyzed farmers' adoption of Soil and Water Conservation Technologies (SWCT) from both internal and external influencing factors of farm households, which is of important reference value. However, these studies lack attention to farmers' experiences with meteorological disasters.

The study adopts imprinting theory to reveal the impact of meteorological disaster shocks on farmers' cognition and behavior (Avital and Jablonka, 1994). From the farmers' perspective, meteorological disaster shocks (MDS) refer to the direct or indirect impacts of meteorological disasters on their production, income, and lives. Since SWTC have the function of resisting natural disaster risks, MDS are closely related to farmers' adoption behavior of SWTC. Farmers' decisions on the use and management of natural resources largely depend on their perception and sensitivity to past experiences. After being impacted by meteorological disasters, farmers adjust their behaviors and measures according to their own circumstances, continuously learn, and proactively adopt SWTC to better cope with future threats (Teshome et al., 2016). MDS will be imprinted in farmers' and collective consciousness, affecting the decision-making and practices of agricultural communities. Moreover, the implementation process and effects of SWTC can improve the surrounding ecological environment, benefit the agricultural production environment of other farmers, and have the attributes of positive externality and non-exclusivity, being typical public goods. Therefore, when studying the relationship between MDS and farmers' adoption behavior of SWTC, it is necessary to consider the role of collective action.

To sum up, there are many research results on farmers' adoption behavior of SWTC, which are of important reference value. However, few studies have analyzed farmers' adoption behavior of such technologies from the perspective of meteorological disaster, and even fewer have integrated MDS, collective action, and farmers' adoption behavior into a unified analytical framework, which provides room for further research in this paper. In view of this, this paper constructs an analytical framework involving MDS, collective action, and farmers' adoption behavior of SWTC. Using survey data of farmers from Shaanxi, Gansu, and Ningxia provinces, it examines and analyzes the impacts of MDS and collective action on farmers' adoption behavior of SWTC, and further explores the differential impacts of MDS on the adoption of such technologies by different types of farmers. The research significance lies in first, it helps improve the theoretical research system of farmers' behavior, providing a new perspective for studying the determinants of adoption behavior of

SWTC from the perspectives of MDS and collective action. Second, based on the imprinting theory, exploring the impact of MDS on farmers' choice of SWTC can enrich the imprinting theory. Third, starting from the characteristics of technology adopters, it can more effectively provide a scientific decision-making basis for policies related to promoting SWTC.

The rest of the paper is structured as follows: Section 2 elaborates on the theoretical analysis framework and research hypotheses, clarifying the logical relationships between key variables; Section 3 explains the research area, data sources, variable descriptions and statistics, and the setting of empirical models; Section 4 presents and analyzes the empirical results, including benchmark regression, mediating effect test, and heterogeneity analysis; Section 5 contains the research conclusions, policy recommendations, and discussions.

Theoretical analysis and hypotheses

The theory of imprinting, originally grounded in the field of biology and subsequently incorporated into the realms of psychology and behavioral science, delves into the concept of enduring individual experiences that remain resilient over time, unaltered by shifting environmental conditions (Marquis and Tilcsik, 2013). This theory wields a profound and persistent influence on an individual's subsequent decision-making processes, affecting their propensity for risk aversion, cognitive learning awareness, and preventive cognition. In the context of farmers' encounters with disasters and their collective responses, imprinting theory offers valuable insights into the intricate mechanisms underpinning resilience and adaptability within agricultural communities (Wigboldus et al., 2016).

A crucial aspect to consider is the expeditious and involuntary acquisition of knowledge. Farmers who have weathered catastrophes such as devastating floods, prolonged droughts, or the emergence of invasive pests undergo a parallel process of acquiring essential skills (Wang et al., 2015; Xie et al., 2021). They acquire the capacity to swiftly recognize early warning signs, adapt their agricultural methodologies, and institute effective measures to mitigate losses and secure their livelihoods (Lin and Chang, 2020). These farmers, equipped with the knowledge and skills necessary for proficient disaster management, frequently convene to exchange their experiences and insights (Thapa et al., 2022). Likewise, collective action nurtures a sense of community and mutual support. It ultimately reinforces the overall resilience of the agricultural community (Ombogoh et al., 2018). It plays an indispensable role in shaping cognitive frameworks and establishing communal norms (Qurniati et al., 2017). The process of imprinting disaster management experiences results in the accumulation of shared knowledge and the development of a collective ethos. This, in turn, significantly influences decision-making processes and the formulation of preparedness plans within the farming community (Belachew et al., 2020). Farmers collaborate to modify their agricultural techniques, conceive more robust strategies for disaster management, and allocate resources for the construction of infrastructure benefiting the entire community. Given the mounting environmental challenges faced by agricultural communities, acknowledging the critical

significance of imprinting theory is imperative in devising effective strategies to enhance disaster resilience (Takayama et al., 2018; Villamayor-Tomas et al., 2019).

The impact of MDS on the adoption behavior of farmers' SWCT

The study adopts imprinting theory to depict the profound impacts of meteorological disaster shocks on farmers' cognition and behavior. It emphasizes how such shocks influence farmers' cognitive structures and decision-making behaviors in the process of agricultural production. Based on existing research, the analysis of the mechanism of farmers' MDS on their adoption of SWCT includes the following three aspects (Rozaki et al., 2021; Fusco et al., 2021): First, farmers who have experienced MDS will increase their risk aversion and enhance their awareness and ability to resist risks (Ullah et al., 2015). Risk aversion to current or future disasters prompts farmers to adopt risk-avoiding strategies. At the same time, SWCT is a MDS-resistant technology that can reduce future ecological and environmental risks, increase agricultural income, and reduce farmers' environmental vulnerability and livelihood vulnerability (Bewket, 2007). Therefore, farmers who have experienced MDS are more inclined to adopt soil and water conservation technologies and then, reduce the current or future risk exposure level of farmers (Belayneh, 2023).

Second, farmers who have experienced MDS will actively enhance their ability to resist MDS by adopting SWCT. Specifically, after being impacted by meteorological disasters, farmers will change their learning awareness, actively acquire and learn information and technologies related to soil and water conservation, thereby strengthening household human capital and material capital. Ultimately, farmers will implement SWCT to prevent and mitigate the negative impacts of future MDS on household agricultural production or household livelihoods.

Third, in China, most people engaged in agricultural and forestry production are middle-aged and elderly, with a strong dependence on land. Moreover, this group of farmers has experienced more MDS (Jarraj et al., 2023; Ogunniyi et al., 2023), which deepens their memories of the losses and risks caused by MDS and induces psychological panic about disaster losses (Qin et al., 2020; Indrawati et al., 2022). Therefore, to reduce farmers' risk exposure levels and potential losses caused by future MDS (Huo et al., 2020), farmers tend to adopt risk avoidance strategies, namely SWCT.

The impact of collective action on the adoption behavior of farmers' SWCT

In 1979, Ostrom et al. (1979) revised and developed Olson's collective action theory and proposed a method to solve the collective action dilemma and explained that an efficient system promotes mutual supervision, and strengthening mutual supervision can ensure that people make credible commitments (Ostrom and Ostrom, 2019). The three mutually restrict and complement each other. At the same time, Jara-Rojas et al.

(2012) believe that collective action can encourage farmers to adopt SWCT. Collective action in this paper refers to farmers' active and passive participation; a sound regulatory mechanism established to achieve common interests or goals—distributing meteorological disaster shock risks and sharing disaster management costs (Liu et al., 2013); an appropriate information transmission mechanism for exchanging information and technologies; collective organizational activities for negotiation (Yang et al., 2005; Huang et al., 2020a).

On the one hand, formal and informal supervision mechanisms and information transmission mechanisms within collective organizations have positive effects on farmers' adoption of soil and water conservation technologies (Wang et al., 2022). Participating in collective action can promote mutually beneficial cooperation between farmers and can effectively learn and acquire new technology and knowledge information in formal collective activities or mutual exchanges among collective organization members, resulting in a “learning by doing” effect (Bizoza, 2014; Pang et al., 2020). Under the supervision of the action organization system and the mutual supervision of members of collective organizations, it is possible to standardize the technical use standards of farmers, improve the quality of agricultural production, and encourage farmers to pay attention to the family income while taking into account the awareness and behavior of ecological environment protection, thereby increasing the adoption rate of soil and water conservation technologies (Dennis and Brondizio, 2020; Ombogoh et al., 2018).

On the other hand, collective action promotes farmers' adoption of soil and water conservation technologies by sharing the risks and costs incurred in the adoption process (Nigussie et al., 2018). The members of the collective organization collectively produce labor, and the unified purchase or cooperative purchase of soil and water conservation technical equipment and agricultural materials can reduce or share the cost of technology adopters (VanOel et al., 2019). Through collective purchase, the bargaining power will be improved, which will reduce the cost of information search and information acquisition and reduce the cost of individual farmers. Transaction costs and risks, realize the interests of members participating in collective action, generate demand-induced effects, form a good mechanism of interest linkage, and promote farmers to adopt SWCT (Gebremeskel et al., 2018; Assefa et al., 2021). However, collective action can actively promote the adoption of soil and water conservation technologies by farmers under the influence of the collective organization's supervision mechanism, information transmission mechanism, and cost-sharing mechanism (Gebremeskel et al., 2018).

The influence mechanism of MDS and collective action on the adoption behavior of farmers' SWCT

This paper adopts a public goods game to discuss how MDS changes individual learning awareness, cooperation awareness, and risk awareness, which in turn leads to prosocial behavior (participation in collective action), diversification of risks or risk losses, and sharing of risk-taking costs (Nyangena, 2008), thereby promoting farmers to adopt SWCT as public goods (Streletskaya

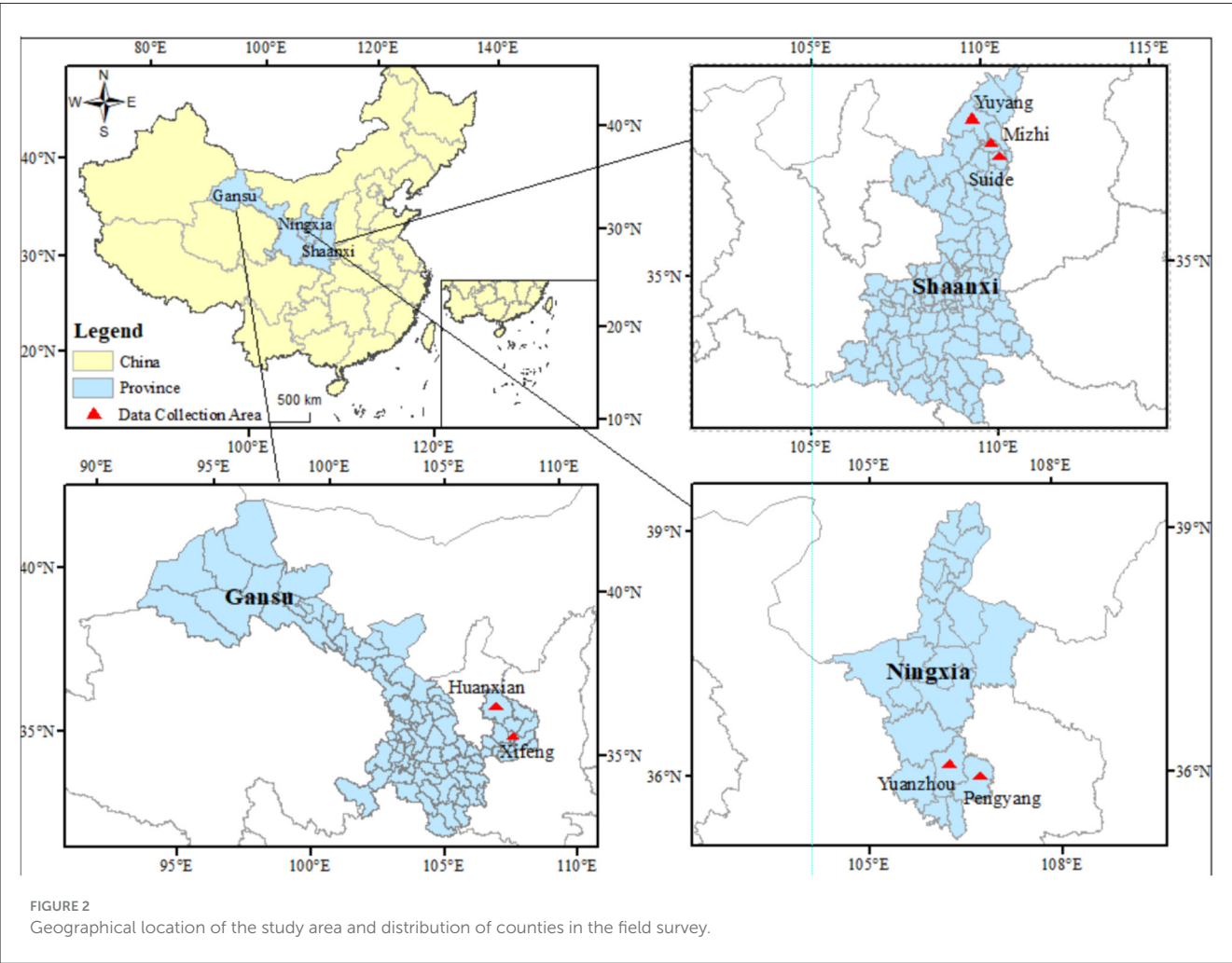
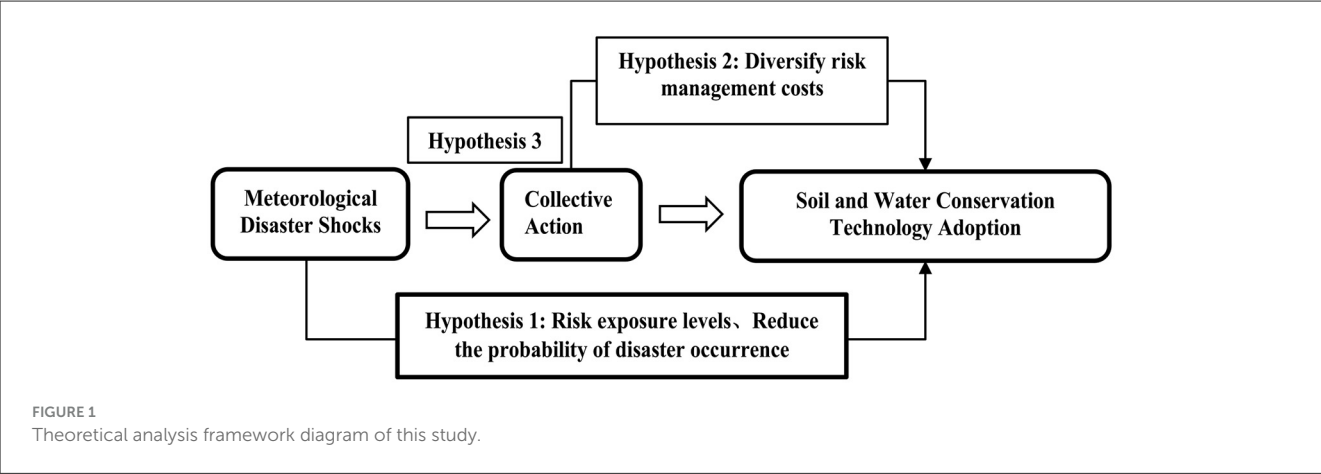
et al., 2020). In reality, after farmers have experienced the impact of MDS, they will become averse to current or future disaster risks and induce panic about past risk losses (Brown et al., 2018; Budhathoki et al., 2020). They will actively establish a restoration and protection mechanism to restore agricultural production. An important approach and means to avoid panic over post-disaster losses and restore agricultural production after disasters is to obtain external funds, technologies, and information. This gives rise to the phenomenon of “huddling together for warmth”. It further promotes the implementation of SWCT, and reduces farmers' risk exposure levels and the probability of MDS (Darkwah et al., 2019; Sileshi et al., 2019).

First, when farmers experience the impact of MDS, participating in village collective activities, cooperatives, and cooperative supply organizations in the village will obtain shared benefits brought about by the rules and regulations set up by the organization (Mekuriaw et al., 2018; Wordofa et al., 2020). During activities, they will take the initiative to strengthen contact with other farmers in the same village by participating in collective actions and overcoming the panic caused by the impact of disasters (Nkegbe and Shankar, 2014; Fallah et al., 2016). Farmers will seek help, whether it is agricultural production materials or emotions, and then strengthen information and technology (Fallah et al., 2016). Communication to increase the adoption rate of farmers' soil and water conservation technologies. Second, when farmers who have experienced the impact of MDS participate in cooperatives, companies, village collective activities, and cooperative supply organizations in the village in order to restore agricultural production, the organization will provide professional technical guidance (Belayneh et al., 2019; Morris and Arbuckle, 2021) and accurate information based on the characteristics of soil and water conservation technologies (Batjes, 2014). Moreover, as a part of the capital investment, they also share the cost of farmers' technology adoption, and increase farmers' behavior of SWCT adoption (Chesterman et al., 2019). Based on the above theoretical analysis, a theoretical analysis framework diagram (Figure 1) has been constructed.

Materials and methods

Data source and sample description

The research data in this paper comes from the questionnaire survey conducted by the research group on grain growers in Northwest China from October to November 2016. Shaanxi Province, Gansu Province, and Ningxia Hui Autonomous Region are all located in the northwest region, belonging to the Loess Plateau area and the irrigation area in the upper and middle reaches of the Yellow River Basin (see Figure 2 Geographical location of the study area and distribution of counties in the field survey.). They are representative areas for key control of soil erosion under the corn and wheat crop planting system. Yang District, Mizhi County and Suide County, Yanzhou District and Pengyang County in Guyuan City, Ningxia Hui Autonomous Region, and Xifeng District and Huan County in Qingyang City, Gansu Province were used as research sites. In most areas of these three provinces, the soil is loose, the terrain is fragmented, vegetation coverage rate is low and the climate is arid. Not only is soil erosion a severe



problem here, but meteorological disasters such as droughts, floods, hailstorms, and sandstorms also occur frequently. These conditions lead to a fragile ecological environment and a decline in crop yields. Therefore, farmers in this area, with both representativeness and diversity, are appropriate survey respondents. This survey adopts a combination of typical sampling and random sampling methods. Specifically, 2–3 counties were selected from each of Shaanxi Province, Gansu Province, and Ningxia Hui Autonomous Region;

3–5 towns were chosen from each county; 2–5 villages were selected from each town; and 20 respondents with communication skills were randomly selected from each village. Finally, after processing outliers and missing values, a total of 1,106 valid samples were obtained, including 334 from Shaanxi Province, 379 from Gansu Province, and 393 from Ningxia Hui Autonomous Region. [Table 1](#) shows the adoption of SWCT by sample farmers in the survey area. It can be found that among the sample farmers,

516 households adopted engineering technology, 141 households adopted biotechnology, and 247 households adopted farming technology, accounting for 46.67%, 12.75%, and 22.33% of the total number of sample farmers, respectively; at the same time, Ningxia farmers adopted the most SWCT, followed by Gansu and Shaanxi.

According to the basic characteristics of the sample farmers (as shown in Table 2), 61% of the respondents are under 55 years old, 56% have received education at or above the junior high school level. Judging from the family land management scale of sample farmers, the proportion of farmers with more than 30 mu reaches 13.20%. From the perspective of the proportion of non-agricultural income, the non-agricultural income of the sample farmers accounted for more than 75% and accounted for 54.07% of the total sample size. Compared with the eastern and central regions with better ecological environments and developed economies, the farmers in the sample areas show a small scale of family land management, and the main source of household income is non-agricultural income.

Variable selection and statistical description

Explained variables

This article selects the core technology of SWCT, including engineering technology, biotechnology, and farming technology. When analyzing the adoption behavior of farmers' SWCT, this paper refers to the method of Mao et al. (2024). The "variable" is set as a dummy variable, 0 means that farmers do not adopt a certain SWCT, and 1 means that farmers have a certain SWCT adoption behavior (as shown in Table 3).

Core explanatory variables and mediator variables

The core explanatory variable selected in this paper is MDS. The core explanatory variable selected in this paper is MDS. Referring to the study by Peng et al. (2020), MDS are treated as a dummy variable. The variable is assigned a value of 1 if the respondent has experienced or suffered MDS. The variable is assigned a value of 0 if the respondent has not. Additionally, collective action is selected as another core explanatory variable and mediating variable. Collective action mainly refers to whether farmers choose to participate in collective organizations such as cooperatives, companies, village collective activities, and spontaneous and autonomous cooperative supply organizations within the village during agricultural production, so as to spread risks, share agricultural production costs, and other related matters. This variable of collective action is also treated as a dummy variable. If the interviewed farmer participates in collective action, the variable is assigned a value of 1. If the interviewed farmer does not participate in collective action, the variable is assigned a value of 0 (as shown in Table 3).

Control variables

According to the existing related research (Huang et al., 2020b; Upadhaya et al., 2023), this paper selects other factors that affect the adoption behavior of farmers' SWCT as control variables, including the personal characteristics of the head of household (age,

education level, cognition of technological, ecological value), family characteristics (proportion of male household labor force, area of land management, number of household agricultural machinery, the proportion of non-agricultural income, whether there are village cadres among family members, and social network) and external environmental characteristics (government subsidies and geographical location). Additionally, the variable of the proportion of male labor force is characterized by the ratio of the number of male laborers to the total number of laborers in the family labor force. The variable of the proportion of non-agricultural income is characterized by the ratio of non-agricultural income to the total household income in family income. The variable of social network is referenced from the research of Ashoori et al. (2016), and is characterized by the number of people with whom the family frequently interacts. The variable of Technology ecological value cognition refers to farmers' cognition of the role of (SWCT) in improving the ecological environment, is measured using a five-level Likert scale.

Model setting

Baseline model

The explained variable is farmers' adoption behavior of soil and water conservation technologies, which specifically includes whether farmers have adopted engineering technologies, biological technologies, or tillage technologies. These are all 0–1 variables, so it is reasonable to use the binary Probit model for regression analysis. The benchmark model set in this paper is as follows:

$$Y_i = a_0 + a_1X_i + a_2C + \delta \quad (1)$$

In equation (1), Y is the explained variable, indicating the adoption behavior of farmers' SWCT, X indicates whether the farmers have experienced MDS or participated in collective actions, C indicates other control variables, and α_i indicates the coefficient to be estimated, which δ is a random error item.

Mediation effect model

To test the intermediary effect, we use the intermediary effect model proposed by Wen and Ye (2014) to analyze the mechanism of action among MDS, collective action, and farmers' SWCT adoption behavior. The model settings are as follows:

$$Y = a_0 + a_1X + a_2C + \delta \quad (2)$$

$$M = \beta_0 + \beta_1X + \beta_2C + \varepsilon \quad (3)$$

$$Y = \gamma_0 + \gamma_1M + \gamma_2X + \gamma_3C + \vartheta \quad (4)$$

In equations (2)–(4), Y is the explained variable, representing farmers' adoption behavior of SWCT; X denotes whether farmers

TABLE 1 Adoption of SWCT by sample farmers in the survey area.

Province	Engineering technology		Biotechnology		Farming technology	
	Number of households	Proportion (%)	Number of households	Proportion (%)	Number of households	Proportion (%)
Gansu	135	12.21	24	2.17	92	8.32
Shaanxi	91	8.23	81	7.32	21	1.90
Ningxia	290	26.22	36	3.25	134	12.12
total	516	46.65	141	12.75	247	22.33

TABLE 2 Distribution characteristics of household heads' age and educational level among sample farmers.

Variable name	Classification	Frequency	Percentage (%)	Variable name	Classification	Frequency	Percentage (%)
Age	Under 45 years old	261	23.60	Land management scale	3 acres and below	99	8.95
	46–55 years old	411	37.16		3–10 acres	392	35.44
	56–65 years old	283	25.59		10–30 acres	469	42.41
	Over 66 years old	151	13.65		30 acres	146	13.20
education level	Illiteracy	186	16.82	Proportion of non-farm income	25% and below	196	17.72
	Primary school	438	39.60		25–50%	110	9.94
	Junior high school	359	32.46		50–75%	202	18.27
	High school and above	123	11.12		More than 75%	598	54.07

have experienced MDS; the mediating variable M indicates whether farmers participate in collective action; C indicates the control variable, while $\alpha_i, \beta_i, \gamma_i$ are the coefficients to be estimated. Specifically, Equation (2) is used to test the impact of MDS on farmers' adoption behavior of SWCT. Equation (3) examines the influence of MDS on farmers' participation in collective action related to SWCT adoption; Equation (4) incorporates both MDS and collective action to verify their combined effect on farmers' adoption behavior of SWCT. The steps for testing the mediating effect in this paper are as follows: First, test whether the coefficient α_1 of Equation (2) is significant. If it is significant, proceed to the next step. Second, sequentially test the coefficient β_1 of Equation (3) and the coefficient γ_1 of Equation (4). If both are significant, the mediating effect is significant, and proceed to the fourth step. If at least one is not significant, proceed to the third step. Third, directly test $H_0: \beta_1\gamma_1 = 0$ using the Bootstrap method. If significant, the mediating effect is significant, and proceed to the fourth step; otherwise, the mediating effect is not significant, and stop the analysis. Fourth, test the coefficient γ_2 of Equation (4). If it is not significant, it indicates that there is only a mediating effect. If it is significant (i.e., the direct effect is significant), proceed to the fifth step. Fifth, compare the signs of $\beta_1\gamma_1$ and γ_2 . If they have the same sign, it is a partial mediating effect.

Results

Before the formal regression analysis of the benchmark model, the correlation coefficient between the variables was preliminarily

tested, and the correlation between MDS, collective action and the adoption behavior of farmers' soil and water conservation technologies was tested more intuitively (see Table 4). It can be seen from Table 4 that there is an obvious positive correlation between MDS and collective action and the adoption of SWCT by farmers, which is consistent with our theoretical analysis. At the same time, considering the possible multi-collinearity among the variables, VIF (variance inflation factor) was used for testing. The test results showed that the maximum VIF value was 1.36, and the VIF values of all variables were less than 10. The variables are independent of each other, and there is no multi-collinearity problem that affects the regression results.

Analysis of benchmark model regression results

The estimated results are shown in Table 5. It can be seen from the regression results that the Wald test values are all significant at the 1% statistical level, indicating that the setting of the model is statistically effective and the overall fit of the model is good.

Models (1), (2), and (3) in Table 5 are the regression results of MDS on farmers' adoption of SWCT. In Model (1), the coefficient for MDS is positive and statistically significant at the 5% level. This indicates that such experience has a positive impact on farmers' adoption behavior of engineering technologies. In Model (2), the coefficient for MDS is positive and statistically significant at the 1% level. This suggests that MDS has a positive impact on farmers'

TABLE 3 Variable definitions, assignments, and statistical descriptions of sample farmers.

Category		Variable name	Variable definitions	AV	SD
Explained variable	Farmers' SWCT adoption behavior	Engineering technology adoption behavior	Whether farmers have adopted engineering technologies such as building terraces, terraces, and fish scale pits (yes = 1, no = 0)	0.4665	0.4991
		Biotechnology adoption behavior	Whether farmers have adopted biotechnology such as planting trees and grasses (yes = 1, no = 0)	0.1274	0.3337
		Farming technology adoption behavior	Whether farmers have adopted farming techniques such as low-tillage and no-tillage, furrow and ridge farming (yes = 1, no = 0)	0.2 233	0.4166
	Core explanatory variable	MDS	whether farmers experienced many droughts, rainstorms, floods, strong winds and hailstones from 2014 to 2016 (yes = 1, no = 0)		0.3376
	Mediator variable	Collective action	whether to participate in cooperatives, companies, collective activities in the village, spontaneous collective organizations in the village (yes = 1, no = 0)		0.4612
Control variable	Personal characteristics of the head of household	Age	Actual age of head of household (years)	53.1066	10.9697
		Education level	Education level of head of household (years)	5.8318	3.7196
		Technology ecological value cognition	The improvement degree of SWCT to the ecological environment of the area (no effect = 1, some effect = 2, general = 3, large effect = 4, very large effect = 4)	0.3943	0.1824
	Family characteristics	The proportion of male labor force	Number of the male labor force in household/total labor force (%)	16.6745	15.7953
		Land management area	Total land area owned by households (mu)	0.0958	0.2945
		Village cadres	Whether the family member has a village cadre (yes = 1, no = 0)	0.4529	0.5692
		Number of farm machinery	The number of agricultural machinery owned by rural households (pieces)	0.6694	0.3364
		Proportion of non-farm income	Household off-farm income/total income (%)	0.6238	0.4846
		Social network	Number of frequent family contacts (number)	61.4719	89.1034
	External environment characteristics	Government subsidies	Whether the government has subsidies for SWCT (yes = 1, no = 0)	1.6031	0.8846
		Gansu	Is it located in gansu (yes = 1, no = 0)	0.3426	0.4748
		Ningxia	Is it located in ningxia (yes = 1, no = 0)	0.3553	0.4788

TABLE 4 Correlation analysis results between core explanatory variables and explained variables.

Variable name	Engineering technology	Biotechnology	Farming technology	MDS	Collective action
Engineering technology	1.0000	—	—	—	—
Biotechnology	0.1316***	1.0000	—	—	—
Farming technology	0.3036***	0.1595***	1.0000	—	—
MDS	0.1270***	0.1164***	0.1054***	1.0000	—
Collective action	0.1736***	0.1659***	0.1069***	0.2240***	1.0000

*, **, and *** indicate significance at the statistical level of 10%, 5%, and 1 %, respectively.

adoption behavior of biological technologies. In Model (3), the coefficient for MDS is positive and statistically significant at the 1% level. This indicates that MDS has a positive impact on farmers' adoption behavior of farming technologies. Based on the above analysis, it is explained that: farmers who have experienced MDS are more inclined to adopt SWCT, the reason is to avoid the risk of MDS, reduce their own risk exposure level, improve the ecological environment of the area and reduce their own risk.

The vulnerability of livelihoods promotes farmers to adopt MDS risk-resisting technologies to increase the adoption rate of soil and water conservation technologies. Hypothesis 1 has been verified. Table 5 outlines the regression results of models (4), (5), and (6), covering the collective action on farmers' adoption of SWCT. The impacts are all significant at the 1% significance level, and the coefficients are positive; it shows that farmers' participation in collective action has a positive effect on farmers' adoption of

TABLE 5 Empirical regression results of the impact of MDS and collective action on farmers' adoption behavior of SWCT.

Variable name	Engineering technology	Biotechnology	Farming technology	Engineering technology	Biotechnology	Farming technology
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
MDS	0.3176** (0.1285)	1.0953*** (0.2434)	0.3109* (0.1604)			
Collective action				0.5252*** (0.0930)	0.6731*** (0.1447)	0.3218*** (0.1047)
Age	0.0029 (0.0041)	0.0010 (0.0054)	0.0055 (0.0046)	0.0031 (0.0041)	0.0009 (0.0053)	0.0052 (0.0046)
Education level	−0.0140 (0.0114)	0.0376** (0.0147)	0.0398*** (0.0126)	−0.0159 (0.0115)	0.0351** (0.0144)	0.0388*** (0.0126)
The proportion of male labor force	0.2648 (0.2278)	0.2524 (0.2924)	0.0285 (0.2524)	0.2248 (0.2289)	0.1916 (0.2943)	0.0125 (0.2546)
Land management area	0.0213*** (0.0034)	0.0140*** (0.0034)	0.0080*** (0.0029)	0.0211*** (0.0035)	0.0128*** (0.0034)	0.0077*** (0.0029)
Village cadres	−0.0583 (0.1476)	0.0644 (0.1794)	0.0352 (0.1543)	−0.0978 (0.1494)	0.0172 (0.1785)	0.0241 (0.1544)
Number of farm machinery	0.0929 (0.0761)	0.1109 (0.0967)	0.3193*** (0.0797)	0.0995 (0.0769)	0.1249 (0.0979)	0.3181*** (0.0799)
Proportion of non-farm income	0.0052 (0.1300)	0.2491 (0.1719)	−0.0473 (0.1431)	−0.0495 (0.1312)	0.0904 (0.1718)	−0.0775 (0.1440)
Government subsidies	0.2850*** (0.0882)	0.1448 (0.1211)	0.0088 (0.0969)	0.2437*** (0.0893)	0.0855 (0.1223)	−0.0169 (0.0975)
Social network	0.0002 (0.0005)	−0.0004 (0.0006)	−0.0007 (0.0006)	0.0001 (0.0005)	−0.0006 (0.0006)	−0.0009 (0.0006)
Technology ecological value cognition	0.0392 (0.0494)	0.2236*** (0.0603)	0.2178*** (0.0525)	0.0236 (0.0498)	0.2452*** (0.0599)	0.2052*** (0.0528)
Gansu (with shaanxi as the reference group)	0.1163 (0.1108)	−1.2119*** (0.1520)	0.6836*** (0.1414)	0.1889* (0.1114)	−1.1347*** (0.1532)	0.7347*** (0.1425)
Ningxia (with shaanxi as the reference group)	1.0204*** (0.1154)	−0.9206*** (0.1502)	1.0575*** (0.1461)	1.0926*** (0.1160)	−0.8184*** (0.1486)	1.0909*** (0.1461)
Constant term	−1.5791*** (0.3299)	−2.8193*** (0.4694)	−2.8783*** (0.3883)	−0.5409* (0.2789)	−3.1454*** (0.3850)	−1.4782*** (0.3047)
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood	−627.3150	−352.6724	−505.6786	−614.1264	−354.3611	−502.8051
Pseudo r2	0.1791	0.1643	0.1391	0.1963	0.1603	0.1440
Wald test value	232.67***	113.73***	132.36***	248.25***	108.45***	138.52***

*, ** and *** indicate significance at the statistical level of 10%, 5%, and 1%, respectively.

engineering technology, biotechnology and farming technology in soil and water conservation technologies, because in reality, soil and water keeping technology with the attribute of public goods, in order to avoid the phenomenon of “free riding”, farmers often realize the supply of public goods through institutional supervision mechanisms of collective action, information communication mechanisms, and cost-sharing mechanisms, that is, to promote the adoption of soil and water conservation technologies by farmers. Behavior, hypothesis 2 was verified.

Among the control variables, the coefficient for the household head's education level is positive, with significance at the 5% and 1% levels respectively. This indicates that farmers with higher education levels are more inclined to adopt these two types of technologies. The potential reason is that such farmers, with higher education, can not only better understand and apply biological and farming technologies but also have a clearer awareness of the risk-resistant functions of these technologies, thus being more willing to adopt them. The coefficient for land management area is positive and significant at the 1% level across all cases. This indicates that the larger the land management area, the more willing farmers are

to adopt SWCT. There are two possible reasons: On one hand, to expand their land management area, farmers use engineering, biological, and farming technologies to convert wasteland and severely desertified land into usable land, thereby promoting the adoption of SWCT. On the other hand, farmers with larger land management areas are more concerned about huge losses caused by MDS risks, so they actively adopt SWCT to avoid such losses.

To avoid MDS, large-scale farmers are more inclined to adopt biotechnology and farming technology. Additionally, the coefficient for the number of agricultural machineries is positive and statistically significant at the 1% level. This indicates that the more agricultural machineries there are, the more inclined farmers are to adopt farming technology. A possible reason is that a greater amount of agricultural machinery makes agricultural production methods more convenient and labor-saving, which in turn makes farmers more inclined to adopt farming techniques. Furthermore, the coefficient for technology ecological value cognition is positive and statistically significant at the 1% level. This indicates that the clearer farmers' cognition of the ecological value of SWCT is, the more it can promote their use of biotechnology and farming

techniques. Moreover, the impact of government subsidies on engineering technology adoption behavior is significant at the 1% significance level, with a positive coefficient, indicating that government subsidies can actively promote farmers' adoption of engineering technology, which is consistent with the research results of Huang et al. (2020c). In addition, the regional dummy variables, taking Shaanxi Province as the reference group, have more significant estimation results, indicating that there are significant regional differences in the adoption of soil and water conservation technologies.

Mediating effect test

Based on the previous theoretical analysis, after experiencing the impact of MDS, farmers participate in collective actions, spread the risks and losses of MDS, and share the cost of post-disaster recovery to affect their behavior of adopting soil and water conservation technologies. In this section, stepwise regression, the Sobel test, and the Bootstrap test are employed to verify the mediating effect of collective action (see Tables 5–7 for details).

Collective action mediates the effect of MDS on engineering technology adoption behavior

Based on the stepwise regression test results of models (1), (7), and (8). Model (1) shows that MDS has a significant positive impact on farmers' engineering technology adoption behavior. Model (7) indicates that MDS also has a positive and significant effect on farmers' participation in collective action. Model (8) reveals that MDS has a positive but insignificant impact on farmers' engineering technology adoption behavior, while collective action exerts a significant positive effect on farmers' engineering technology adoption behavior. These results suggest that collective action plays a complete mediating role in the process where MDS affect farmers' engineering technology adoption behavior. Results from the Sobel test and Bootstrap test show the following. In the path where MDS affects farmers' engineering technology adoption behavior, the mediating effect value of collective action is 0.0528, accounting for 52.31% of the total effect. Its confidence interval is (0.0315, 0.0777), which is significant at the 95% confidence level (see Table 7 for details). Hypothesis 3 is thus confirmed.

Collective action plays a mediating role in the impact of MDS on biotechnology adoption behavior

Based on the stepwise regression results of models (2), (7), and (9). In model (2), MDS has a significant positive impact on farmers' biotechnology adoption behavior. In model (7), MDS exerts a significant positive effect on farmers' participation in collective action. Model (9) shows that MDS has a significant positive impact on farmers' biotechnology adoption behavior, and collective action also has a significant positive impact on farmers' biotechnology adoption behavior. These results indicate that collective action plays a partial mediating role in the process where MDS affects farmers' biotechnology adoption behavior. It has a mediating role in the impact process (see Tables 5, 6). From the Sobel test and

self-sampling test, it can be concluded that the mediation effect is 0.0232, accounting for 15.97% of the total effect, and the confidence interval is (0.0119, 0.0377), which is significant at the 95% confidence level. There was no masking effect (see Table 7). These results further confirm hypothesis 3.

Collective action plays a mediating role in the impact of MDS on farming technology adoption behavior

Based on the stepwise regression results of models (3), (7), and (10): In model (3), MDS has a significant positive impact on farmers' farming technology adoption behavior. In model (7), MDS exerts a significant positive effect on farmers' participation in collective action. In model (10), the influence coefficient of MDS on farmers' farming technology adoption behavior is positive but insignificant, while collective action has a positive and significant impact on farmers' farming technology adoption behavior. These findings indicate that collective action plays a complete mediating role in the process where MDS affects farmers' farming technology adoption behavior (see Tables 5, 6). From the Sobel test and self-sampling test, it can be concluded that the mediation effect is 0.0250, accounting for 47.73% of the total effect, and the confidence interval is (0.0099, 0.0428), which is significant at the 95% confidence level. There was no masking effect (see Table 7). Hypothesis 3 was further verified.

Robustness test

Since the explained variable is a binary selection variable, there may be a sample bias problem. In order to verify whether the impact of the above-mentioned MDS on farmers' SWCT adoption behavior is robust, this paper constructs a counterfactual analysis framework and uses the propensity score matching method (PSM) to measure the net effect of MDS on engineering technology, biotechnology, and farming technology in soil and water conservation technologies. Specifically, first, the experimental group was set as having MDS or participating in collective action and the control group as having no MDS and not participating in collective action. The logit model was used to calculate the score of each sample farmer. Second, three matching methods were selected for matching between the experimental group and the control group: K-nearest neighbor matching ($K = 4$), caliper matching (caliper = 0.020), and kernel matching (bandwidth = 0.060). Finally, the results of the average treatment effect (ATT) were obtained (as shown in Table 8). It is found that the results of the robustness test are basically consistent with the conclusions of the benchmark regression analysis.

Group difference analysis

The probit model was used above to measure the impact of MDS on the adoption of soil and water conservation technologies by farmers, but it could not reflect the differences in the adoption of soil and water conservation technologies by MDS of farmers

TABLE 6 Test of the mediating effect of collective action in the impact of MDS on farmers’ adoption behavior of SWCT (Stepwise regression method result).

Variable name	Collective action	Engineering technology	Biotechnology	Farming technology
	Model (7)	Model (8)	Model (9)	Model (10)
MDS	0.3186*** (0.0407)	0.1598 (0.1345)	0.9921*** (0.2472)	0.1977 (0.1649)
Collective action		0.4994*** (0.0955)	0.5894*** (0.1483)	0.2878*** (0.1082)
Age	−0.0001 (0.0013)	0.0031 (0.0041)	0.0006 (0.0054)	0.0052 (0.0046)
education level	0.0011 (0.0037)	−0.0154 (0.0115)	0.0374** (0.0147)	0.0395*** (0.0126)
The proportion of male labor force	0.0138 (0.0733)	0.2358 (0.2294)	0.2504 (0.3011)	0.0167 (0.2548)
Land management area	0.0014 (0.0010)	0.0212*** (0.0035)	0.0135*** (0.0035)	0.0077*** (0.0029)
Village cadres	0.0551 (0.0476)	−0.0949 (0.1496)	0.0411 (0.1814)	0.0237 (0.1545)
Number of farm machinery	0.0080 (0.0248)	0.0969 (0.0769)	0.1126 (0.0985)	0.3172*** (0.0799)
Proportion of non-farm income	0.0815* (0.0421)	−0.0323 (0.1319)	0.2046 (0.1752)	−0.0651 (0.1443)
Government subsidies	0.0921*** (0.0289)	0.2455*** (0.0894)	0.0965 (0.1240)	−0.0138 (0.0976)
Social network	0.0003* (0.0002)	0.0001 (0.0005)	−0.0006 (0.0006)	−0.0008 (0.0006)
Technology ecological value cognition	0.0417** (0.0164)	0.0175 (0.0500)	0.2136*** (0.0609)	0.2008*** (0.0529)
Gansu (with Shaanxi as the reference group)	−0.1146*** (0.0365)	0.1720 (0.1123)	−1.2310*** (0.1561)	0.7241*** (0.1430)
Ningxia (with Shaanxi as the reference group)	−0.0666* (0.0381)	1.0723*** (0.1171)	−0.9177*** (0.1524)	1.0767*** (0.1470)
Constant term	0.2463** (0.1060)	−0.8208*** (0.3046)	−3.8341*** (0.4539)	−1.7504*** (0.3352)
Prob > chi2	—	0.0000	0.0000	0.0000
Log Likelihood	—	−613.4169	−342.8219	−502.0662
Pseudo R 2	0.0916	0.1972	0.1853	0.1452
Wald test value	9.58***	249.30***	120.40***	138.43***

*, ** and *** indicate significance at the statistical level of 10%, 5%, and 1%, respectively.

TABLE 7 Test of the mediating effect of collective action in the impact of MDS on farmers’ adoption behavior of SWCT (Sobel test and self-sampling test results).

Influence path	Sobel test				Self-sampling test (Bootstrap test)			Is the mediation effect significant?
	Indirect effect	Direct effect	Total effect	Proportion of mediating effect or amount of masking effect	Indirect effect	95% confidence interval		
						Lower limit	Upper limit	
i. MDS→ collective action→ engineering technology	0.0506*** (0.0120)	0.1371** (0.0447)	0.1877*** (0.0441)	52.31%	0.0506*** (0.0117)	0.0261	0.0789	The complete mediation effect is significant.
ii. MDS→ Collective Action→ Biotechnology	0.0326*** (0.0079)	0.0824** (0.0300)	0.1150*** (0.0295)	28.35%	0.0326*** (0.0071)	0.0205	0.0471	The mediating effect is significant.
iii. MDS→ collective action→ farming technology	0.0242** (0.0090)	0.1058** (0.0377)	0.1300*** (0.0369)	18.65%	0.0242** (0.0091)	0.0076	0.0439	The complete mediation effect is significant.

*, ** and *** indicate significance at the statistical level of 10%, 5%, and 1%, respectively.

with different characteristics. It is helpful to explore the group differences of different types of farmers to enrich the research content of MDS on farmers’ technology choice behavior. based on previous research (Ademe et al., 2017), this paper divides the age of household heads into two categories: the young generation (55 years old and below) and the old generation (55 years old and above); the education level of household heads are divided into low education (9 years and below) and high education (more than 9 years) divide the scale of land management into two types—small-scale (less than 10 mu) and large-scale (10 mu and above). The Probit model was used to test the differences in the adoption behaviors of soil and

TABLE 8 Robustness test results of the impact of MDS and collective action on farmers' adoption behavior of SWCT.

Variable name	Matching method	ATT (MDS Experience)	T-value	Variable name	Matching method	ATT (Work in group)	T-value
Engineering technology	K-nearest neighbor matching (K = 4)	0.1032* (0.0563)	1.99	Engineering technology	K-nearest neighbor matching (K = 4)	0.1797*** (0.0404)	5.03
	Caliper matching (caliper = 0.020)	0.1124* (0.0519)	2.20		Caliper matching (caliper = 0.020)	0.1751*** (0.0346)	5.15
	Kernel matching (broadband = 0.060)	0.1207** (0.0498)	2.46		Kernel matching (broadband = 0.060)	0.1751*** (0.0321)	5.26
Biotechnology	K nearest neighbor matching (K = 4)	0.1332*** (0.0136)	6.36	Biotechnology	K nearest neighbor matching (K = 4)	0.1055*** (0.0225)	5.55
	Caliper matching (caliper = 0.020)	0.1331*** (0.0132)	6.43		Caliper matching (caliper = 0.020)	0.1057*** (0.0207)	5.74
	Kernel matching (broadband = 0.060)	0.1332*** (0.0129)	6.64		Kernel matching (broadband = 0.060)	0.1306*** (0.0188)	5.73
Farming technology	K nearest neighbor matching (K = 4)	0.0915* (0.0485)	2.50	Farming technology	K nearest neighbor matching (K = 4)	0.0956** (0.0279)	3.35
	Caliper matching (caliper = 0.020)	0.0736* (0.0436)	2.07		Caliper matching (caliper = 0.020)	0.1107*** (0.0253)	4.08
	Kernel matching (broadband = 0.060)	0.0821* (0.0391)	2.48		Kernel matching (broadband = 0.060)	0.1109*** (0.0242)	4.16

water conservation technologies after different groups of farmers experienced MDS.

As shown in Table 9, there are obvious inter-group differences in the impact of MDS on farmers' SWCT adoption behavior, which shows that the age of the household head, the education level of the household head, and the scale of land management will affect the MDS of the farmers, and then affect farmers' adoption behavior of soil and water conservation technologies. In terms of different age groups, after the younger generation of farmers experienced MDS, the probability of adopting engineering technology increased by 40.37%; after the older generation of farmers experienced MDS, the probability of adopting farming technology increased by 54.20%. The younger the age, the more obvious the improvement in the adoption of engineering technology after experiencing MDS on the contrary, the older the household head, the greater the improvement in the adoption of farming technology after experiencing MDS. The possible reason is that the household head is young and can invest, the labor force is relatively large, and the adoption of engineering technology requires a large amount of continuous labor input, which leads to the fact that farmers with younger household heads tend to adopt engineering technology after experiencing MDS, the older the household head, the higher the degree of dependence on their own farmland.

As far as different educational levels are concerned, after the farmers with low education experience MDS, the probability of adopting engineering technology increases by 30.78%, and the probability of adopting farming technology increases by 40.36%. The improvement of SWCT's engineering technology adoption behavior and farming technology adoption behavior is more obvious. A possible reason is that compared with educated farmers, low-educated farmers lack re-employment ability after experiencing MDS and rely on land. If the degree is high, the enthusiasm for restoring agricultural production is strong, and they will tend to adopt farming technology, and they will also

be more inclined to adopt engineering technology to increase the area of land management. As far as the scale of land management is concerned, after small-scale farmers MDS, the probability of adopting engineering technology increases significantly by 43.58%, while after large-scale farmers MDS, the improvement in engineering technology adoption is not significant, which fully demonstrates the driving effect of MDS on the adoption of engineering technology by small-scale farmers is that large-scale farmers tend to adopt engineering technology in order to avoid MDS and expand the scale of land management after experiencing MDS.

Discussion

The discussion in this paper mainly includes the following two aspects: (1) Research findings and theoretical connection. This study verifies that MDS have a significant positive impact on farmers' adoption of SWCT, which is consistent with the logic of imprinting theory: disaster experiences drive farmers to take adaptive behaviors by shaping their risk perception and decision-making patterns. Meanwhile, the mediating effect of collective action indicates that farmers' cooperative behaviors (such as risk sharing and information sharing) after disaster shocks are an important transmission path for technology adoption, which echoes the view in Ostrom's collective action theory that "institutional arrangements promote the supply of public goods". (2) Dialogue with existing research. Most existing studies analyze the impact of disaster shocks or collective action in isolation, while this study incorporates both into a unified framework, revealing the chain mechanism of "disaster shocks→ collective action→ technology adoption" and making up for the fragmented limitations of previous studies. For example, compared with studies that only focus on external factors such as government subsidies,

TABLE 9 Group difference analysis results of the impact of MDS and collective action on farmers’ adoption behavior of SWCT.

Different age groups						
Variable name	Engineering technology		Biotechnology		Farming technology	
	Model (11)	Model (12)	Model (13)	Model (14)	Model (15)	Model (16)
	Young generation	Old generation	Young generation	Old generation	Young generation	Old generation
MDS experience	0.4037** (0.1788)	0.2261 (0.1871)	1.4365*** (0.4512)	1.4365*** (0.4512)	0.2088 (0.2050)	0.5420** (0.2693)
Control variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant term	−1.9008*** (0.3286)	−0.9661*** (0.3132)	−3.3454*** (0.5968)	−3.3454*** (0.5968)	−2.8843*** (0.3988)	−2.3098*** (0.4034)
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log Likelihood	−345.0007	−273.7055	−179.5066	−167.9299	−303.9106	−192.9985
Pseudo R2	0.2009	0.1637	0.1801	0.172	0.0.1385	0.1637
	Model (17)	Model (18)	Model (19)	Model (20)	Model (21)	Model (22)
	Lower education	Highly educated	Lower education	Highly educated	Lower education	Highly educated
MDS experience	0.3078* (0.1607)	0.3518 (0.2267)	0.8727*** (0.2854)	1.7412*** (0.5031)	0.4036* (0.2220)	0.2086 (0.2399)
Control variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant term	−1.4993*** (0.3888)	−1.9574*** (0.5937)	−2.4896*** (0.5488)	−3.0638*** (0.8662)	−2.8221*** (0.4852)	−2.5228*** (0.6281)
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log Likelihood	−441.3698	−173.2128	−242.4249	−105.8656	−330.0077	−165.7577
Pseudo R2	0.1949	0.1969	0.1428	0.2280	0.1646	0.1141
	Massive	Small scale	Massive	Small scale	Massive	Small scale
MDS experience	0.2535 (0.1737)	0.4358** (0.1982)	1.1880*** (0.3559)	1.1341*** (0.3547)	0.3027 (0.2115)	0.3908 (0.2568)
Control variable	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant term	−0.8270* (0.4323)	−1.6375*** (0.5109)	−2.1787*** (0.6226)	−3.3932*** (0.7669)	−2.4861*** (0.4998)	−3.5099*** (0.6941)
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log Likelihood	−370.1559	−250.6521	−213.1237	−136.0230	−330.4184	−167.8957
Pseudo R2	0.1048	0.1612	0.1498	0.2004	0.1215	0.0983

this study emphasizes the role of farmers’ endogenous cooperative behaviors, providing a more comprehensive explanation for understanding the promotion of SWCT, a technology with the attribute of public goods. It allows decision-makers, academics, and agricultural professionals to build focused policies that capitalize on the lessons acquired from previous catastrophes and harness the power of collaborative efforts. If we do this, we can make farming communities more resilient, reduce the adverse effects of climate change, and encourage sustainable agricultural practices that are good for farmers and the environment.

Conclusion and policy implications

Conclusion

This paper analyzed the impacts of MDS and collective action on farmers’ adoption behavior of soil and water conservation

technologies, using data from 1,106 respondents across Shaanxi, Gansu, and Ningxia provinces in China. The following conclusions are reached based on our analysis: First, among farmers’ adoption behaviors of soil and water conservation technologies, engineering technologies account for 46.67% of the total sample, biological technologies account for 12.75%, and tillage technologies account for 22.33%. This indicates that the overall level of farmers’ adoption of soil and water conservation technologies is not high, with particularly low adoption rates for tillage technologies and biological technologies. Second, MDS and collective action can significantly promote farmers’ engineering technology adoption, biotechnology adoption, and farming technology adoption; third, collective action plays a role in the process of MDS on farmers’ SWCT adoption. In terms of the positive mediation effect, there are significant inter-group differences in the impact of MDS on farmers’ adoption of soil and water conservation technologies. Compared with other types of farmers, the improvement in behavior is more obvious; the farmers with household heads aged

55 years and below and with low education have experienced MDS, and the improvement of farming technology adoption behavior is more obvious.

Policy implications

Based on the above conclusions, the following policy implications are drawn: (1) In response to the low adoption rates of tillage and biological technologies, it is necessary to optimize technology supply. Meanwhile, the “cooperative add demonstration household” model should be adopted to strengthen promotion efforts, thereby improving the popularity of these underdeveloped technologies. (2) Given the promotional effects of MDS and collective actions, a linkage mechanism integrating “risk perception-organizational collaboration-technology implementation” should be established. Specifically, early warning popularization and collective procurement can be utilized to reduce the costs of technology adoption. (3) Leveraging the mediating effect of collective actions, it is essential to improve institutional guarantees and interest linkage mechanisms. This will serve to enhance the pivotal role of collective actions in technology promotion. (4) Focusing on the key group of farmers whose household heads are aged 55 or below with low educational levels, hierarchical training and resource inclination policies should be implemented. Special subsidies and credit support can be employed to stimulate their enthusiasm for technology adoption, thus forming a precise and efficient promotion system.

Data availability statement

The datasets presented in this article are not readily available because other participants are not allowed to make it public. Requests to access the datasets should be directed to dxl7482@gsupl.edu.cn.

Ethics statement

The studies involving humans were approved by Gansu University of Political science and Law. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

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

administration, Resources, Supervision, Visualization, Writing – review & editing. WZ: Methodology, Project administration, Resources, Supervision, Visualization, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. Youth Project of Humanities and Social Sciences, Ministry of Education; National Natural Science Foundation of China; Scientific Research Project of Gansu University of Political Science and Law Funding role: Provided relevant financial support for the core data collection, field research, preliminary analysis, academic exchanges, paper writing, and final improvement of the research results.

Acknowledgments

The authors would like to express their gratitude to the smallholder farmers who grow watermelons and muskmelons in the central and western regions of China for their time and participation during the field data collection. At the same time, the authors also want to thank those who have dedicated their time and efforts to this project and have sorted out relevant materials and data. These individuals include: Qu Yufei, Zhang Wenying, and many staff members and student assistants.

Conflict of interest

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

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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

Publisher's note

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

References

- Ademe, Y., Kebede, T., Mullatu, A., and Shafi, T. (2017). Evaluation of the effectiveness of soil and water conservation practices on improving selected soil properties in Wonago district, Southern Ethiopia. *J. Soil Sci. Environ. Manage.* 8, 70–79. doi: 10.5897/JSEM2016.0601
- Altobelli, F., Vargas, R., Corti, G., Dazzi, C., Montanarella, L., Monteleone, A., et al. (2020). Improving soil and water conservation and ecosystem services by sustainable soil management practices: from a global to an Italian soil partnership. *Ital. J. Agron.* 15:1765. doi: 10.4081/ija.2020.1765
- Ashoori, D., Bagheri, A., Sadegh, M., and Michailidis, A. (2016). Understanding the attitudes and practices of paddy farmers for enhancing soil and water conservation in Northern Iran. *Int. Soil Water Conserv. Res.* 4, 260–266. doi: 10.1016/j.iswcr.2016.09.003
- Assefa, S., Kessler, A., and Fleskens, L. (2021). Using agent-based modelling to assess scenarios for enhanced soil and water conservation in the Boset District, Ethiopia. *J. Artif. Soc. Soc. Simul.* 24:1. doi: 10.18564/jasss.4714
- Avital, E., and Jablonka, E. (1994). Social learning and the evolution of behaviour. *Anim. Behav.* 48, 1195–1199. doi: 10.1006/anbe.1994.1351
- Batjes, N. H. (2014). Projected changes in soil organic carbon stocks upon adoption of recommended soil and water conservation practices in the Upper Tana River catchment, Kenya. *Land Degrad. Dev.* 25, 278–287. doi: 10.1002/ldr.2141
- Belachew, A., Mekuria, W., and Nachimuthu, K. (2020). Factors influencing adoption of soil and water conservation practices in the northwest Ethiopian highlands. *Int. Soil Water Conserv. Res.* 8, 80–89. doi: 10.1016/j.iswcr.2020.01.005
- Belayneh, M. (2023). Factors affecting the adoption and effectiveness of soil and water conservation measures among small-holder rural farmers: the case of Gumara watershed. *Resour. Conserv. Recycl. Adv.* 18:200159. doi: 10.1016/j.rcradv.2023.200159
- Belayneh, M., Yirgu, T., and Tsegaye, D. (2019). Effects of soil and water conservation practices on soil physicochemical properties in Gumara watershed, Upper Blue Nile Basin, Ethiopia. *Ecol. Process.* 8, 1–14. doi: 10.1186/s13717-019-0188-2
- Bewket, W. (2007). Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: acceptance and adoption by farmers. *Land Use Policy* 24, 404–416. doi: 10.1016/j.landusepol.2006.05.004
- Bizozo, A. R. (2014). Three-stage analysis of the adoption of soil and water conservation in the highlands of Rwanda. *Land Degrad. Dev.* 25, 360–372. doi: 10.1002/ldr.2145
- Brown, P., Daigneault, A. J., Tjernström, E., and Zou, W. (2018). Natural disasters, social protection, and risk perceptions. *World Dev.* 104, 310–325. doi: 10.1016/j.worlddev.2017.12.002
- Budhathoki, N. K., Paton, D., Lassa, J. A., and Zander, K. K. (2020). Assessing farmers' preparedness to cope with the impacts of multiple climate change-related hazards in the Terai lowlands of Nepal. *Int. J. Disaster Risk Reduct.* 49:101656. doi: 10.1016/j.ijdrr.2020.101656
- Cao, Y., Wang, B., Guo, H., Xiao, H., and Wei, T. (2017). The effect of super absorbent polymers on soil and water conservation on the terraces of the loess plateau. *Ecol. Eng.* 102, 270–279. doi: 10.1016/j.ecoleng.2017.02.043
- Chen, Y., Vanmaercke, M., Jiao, J., Bai, L., Tang, B., Wang, N., et al. (2023). Quantifying the importance of different erosion processes and soil and water conservation measure collapses following an extreme rainstorm in the Chinese Loess Plateau. *Land Degrad. Dev.* 34, 403–422. doi: 10.1002/ldr.4468
- Chesterman, N. S., Entwistle, J., Chambers, M. C., Liu, H. C., Agrawal, A., and Brown, D. G. (2019). The effects of trainings in soil and water conservation on farming practices, livelihoods, and land-use intensity in the Ethiopian highlands. *Land Use Policy* 87:104051. doi: 10.1016/j.landusepol.2019.104051
- Cui, Z., Yu, Z., and Gong, X. (2023). Study on the income-increasing effect of conservation tillage technology - A case study of reduced and no-tillage technology. *Chinese J. Agric. Resour. Reg. Plan.* 44, 59–69.
- Danso-Abbeam, G. (2022). Do agricultural extension services promote adoption of soil and water conservation practices? Evidence from Northern Ghana. *J. Agric. Food Res.* 10:100381. doi: 10.1016/j.jafr.2022.100381
- Darkwah, K. A., Kwawu, J. D., Agyire-Tettey, F., and Sarpong, D. B. (2019). Assessment of the determinants that influence the adoption of sustainable soil and water conservation practices in Techiman Municipality of Ghana. *Int. Soil Water Conserv. Res.* 7, 248–257. doi: 10.1016/j.iswcr.2019.04.003
- Dennis, E. M., and Brondizio, E. (2020). Problem framing influences linkages among networks of collective action situations for water provision, wastewater, and water conservation in a metropolitan region. *Int. J. Commons* 14:18. doi: 10.5334/ijc.974
- Fallah, M., Kavian, A., and Omidvar, E. (2016). Watershed prioritization in order to implement soil and water conservation practices. *Environ. Earth Sci.* 75, 1–17. doi: 10.1007/s12665-016-6035-1
- Fontes, F. P. (2020). SWCT adoption and labour allocation: evidence from Ethiopia. *World Dev.* 127:104754. doi: 10.1016/j.worlddev.2019.104754
- Fusco, G., Vecchio, Y., Porrini, D., and Adinolfi, F. (2021). Improving the economic sustainability of Italian Farmer: an empirical analysis of decision-making models for insurance adoption. *New Medit* 3, 53–68.
- Gebremeskel, G., Gebremicael, T. G., and Girmay, A. (2018). Economic and environmental rehabilitation through soil and water conservation, the case of Tigray in northern Ethiopia. *J. Arid Environ.* 151, 113–124. doi: 10.1016/j.jaridenv.2017.12.002
- Gu, C., Zhu, Y., Li, R., Yao, H., and Mu, X. (2021). Effects of different soil and water conservation measures on hydrological extremes and flood processes in the Yanhe River, Loess Plateau, China. *Nat. Hazards* 109, 545–566. doi: 10.1007/s11069-021-04848-w
- Hu, Y., Zhang, F., Luo, Z., Badreldin, N., Benoy, G., and Xing, Z. (2023). Soil and water conservation effects of different types of vegetation cover on runoff and erosion driven by climate and underlying surface conditions. *Catena* 231:107347. doi: 10.1016/j.catena.2023.107347
- Huang, X., Lu, Q., and Wang, L. (2020a). Research on capital endowment, ecological cognition and farmers' water and soil conservation technology adoption behavior—based on the moderating effects of ecological compensation policies. *Agric. Technol. Econ.* 12, 33–44.
- Huang, X., Lu, Q., Wang, L., Cui, M., and Yang, F. (2020b). Does aging and off-farm employment hinder farmers' adoption behavior of SWCT in the Loess Plateau? *Int. J. Clim. Change Strateg. Manag.* 12, 92–107. doi: 10.1108/IJCCSM-04-2019-0021
- Huang, X., Lu, Q., and Yang, F. (2020c). The effects of farmers' adoption behavior of soil and water conservation measures on agricultural output. *Int. J. Clim. Change Strateg. Manag.* 12, 599–615. doi: 10.1108/IJCCSM-02-2020-0014
- Huang, X. H., Wang, L. L., and Lu, Q. (2019). Research on behavior of farmers' adoption of SWCT—an empirical analysis based on data collected from 1152 households on Loess Plateau. *J. Northwest A&F Univ. (Soc. Sci. Ed.)* 19, 133–141.
- Huo, J., Yu, X., Liu, C., Chen, L., Zheng, W., Yang, Y., and Tang, Z. (2020). Effects of soil and water conservation management and rainfall types on runoff and soil loss for a sloping area in North China. *Land Degrad. Dev.* 31, 2117–2130. doi: 10.1002/ldr.3584
- Indrawati, D. R., Supangat, A. B., Wahyuningrum, N., and Subandrio, B. (2022). Community participation in soil and water conservation as a disaster mitigation effort. *IOP Conf. Ser. Earth Environ. Sci.* 1109, 012030. doi: 10.1088/1755-1315/1109/1/012030
- Jara-Rojas, R., Bravo-Ureta, B. E., and Diaz, J. (2012). Adoption of water conservation practices: a socioeconomic analysis of small-scale farmers in Central Chile. *Agric. Syst.* 110, 54–62. doi: 10.1016/j.agry.2012.03.008
- Jarray, F., Hermassi, T., Mechergui, M., Zucca, C., and Le, Q. B. (2023). Long-term impact of soil and water conservation measures on soil erosion in a tunisian semi-arid watershed. *Land* 12:1537. doi: 10.3390/land12081537
- Jia, R., and Lu, Q. (2018). Does land transfer promote the implementation of soil and water conservation measures by rural households in the Loess Plateau region? — an analysis based on the mediating role of collective action and the moderating effect of government subsidies. *Chin. Rural Econ.* 6, 38–54.
- Jia, R., and Lu, Q. (2019). The impact of migrant work and women's decision-making on farmers' participation in collective actions - A case study based on survey data of farmers in Shaanxi, Gansu and Ningxia Provinces. *J. Agrotech. Econ.* 122–134.
- Jiang, C., Zhang, H., Wang, X., Feng, Y., and Labzovskii, L. (2019). Challenging the land degradation in China's Loess Plateau: benefits, limitations, sustainability, and adaptive strategies of soil and water conservation. *Ecol. Eng.* 127, 135–150. doi: 10.1016/j.ecoleng.2018.11.018
- Kpadonou, R. A. B., Owiyo, T., Barbier, B., Denton, F., Rutabingwa, F., and Kiema, A. (2017). Advancing climate-smart-agriculture in developing drylands: joint analysis of the adoption of multiple on-farm soil and water conservation technologies in West African Sahel. *Land Use Policy* 61, 196–207. doi: 10.1016/j.landusepol.2016.10.050
- Lei, X., Li, J., Li, H., Yan, J., Li, P., Guo, Y., et al. (2023). Regional assessment at the province level of agricultural science and technology development in China. *Agriculture* 13:389. doi: 10.3390/agriculture13020389
- Li, L., Dingyi, S., Xiaofang, L., and Zhide, J. (2021). Influence of peasant household differentiation and risk perception on soil and water conservation tillage technology adoption—an analysis of moderating effects based on government subsidies. *J. Clean. Prod.* 288:125092. doi: 10.1016/j.jclepro.2020.125092
- Lin, P. S. S., and Chang, K. M. (2020). Metamorphosis from local knowledge to inviolated disaster knowledge for disaster governance in a landslide-prone tribal community in Taiwan. *Int. J. Disaster Risk Reduct.* 42:101339. doi: 10.1016/j.ijdrr.2019.101339
- Lingling, L., Renzhi, Z., Zhuzhu, L., Wei, L., Junhong, X., Liqun, C., and Bellotti, B. (2014). Evolution of soil and water conservation in rain-fed areas of China. *Int. Soil Water Conserv. Res.* 2, 78–90. doi: 10.1016/S2095-6339(15)30015-0
- Liu, G., Dai, F., Nan, L., and Du, S. (2013). Assessing the suitability of soil and water conservation practices in Southwestern China. *Land Use Policy* 30, 319–327. doi: 10.1016/j.landusepol.2012.03.022

- Mao, H., Chen, S., and Fu, Y. (2024). Policy incentives and farmers' adoption of soil and water conservation technologies: an empirical analysis based on farmers in Shaanxi Province of the Yellow River Basin. *J. Jiangxi Univ. Financ. Econ.* 3, 91–101. doi: 10.13676/j.cnki.cn36-1224/f.20231030.001
- Marquis, C., and Tilcsik, A. (2013). Imprinting: toward a multilevel theory. *Acad. Manag. Ann.* 7, 195–245. doi: 10.5465/19416520.2013.766076
- Mekuriaw, A., Heinemann, A., Zeleke, G., and Hurni, H. (2018). Factors influencing the adoption of physical soil and water conservation practices in the Ethiopian highlands. *Int. Soil Water Conserv. Res.* 6, 23–30. doi: 10.1016/j.iswcr.2017.12.006
- Morris, C., and Arbuckle, J. G. (2021). Conservation plans and soil and water conservation practice use: evidence from Iowa. *J. Soil Water Conserv.* 76, 457–471. doi: 10.2489/jswc.2021.00166
- Nigusie, Z., Tsunekawa, A., Haregeweyn, N., Adgo, E., Cochrane, L., Floquet, A., and Abele, S. (2018). Applying Ostrom's institutional analysis and development framework to soil and water conservation activities in north-western Ethiopia. *Land Use Policy* 71, 1–10. doi: 10.1016/j.landusepol.2017.11.039
- Nkegbe, P. K., and Shankar, B. (2014). Adoption intensity of soil and water conservation practices by smallholders: evidence from Northern Ghana. *Bio-based Appl. Econ. J.* 3, 159–174. doi: 10.13128/BAE-13246
- Nyangena, W. (2008). Social determinants of soil and water conservation in rural Kenya. *Environ. Dev. Sustain.* 10, 745–767. doi: 10.1007/s10668-007-9083-6
- Ogunniyi, A. I., Omotayo, A. O., Olagunju, K. O., Motunrayo, O., Awotide, B. A., and Mavrotas, G., et al. (2023). Do soil and water conservation practices influence crop productivity and household welfare? Evidence from rural Nigeria. *Environ. Sci. Pollut. Res.* 30, 56016–56036. doi: 10.1007/s11356-023-26280-2
- Ojo, T. O., Baiyegunhi, L. J., Adetoro, A. A., and Ogundej, A. A. (2021). Adoption of SWCT and its effect on the productivity of smallholder rice farmers in Southwest Nigeria. *Heliyon* 7:e06433. doi: 10.1016/j.heliyon.2021.e06433
- Ombogoh, D. B., Tanui, J., McMullin, S., Muriuki, J., and Mowo, J. (2018). Enhancing adaptation to climate variability in the East African highlands: a case for fostering collective action among smallholder farmers in Kenya and Uganda. *Clim. Dev.* 10, 61–72. doi: 10.1080/17565529.2016.1174665
- Ostrom, E., Parks, R. B., Percy, S. L., and Whitaker, G. P. (1979). Evaluating police organization. *Public Prod. Rev.* 3, 3–27.
- Ostrom, V., and Ostrom, E. (2019). "Public goods and public choices," in *Alternatives for Delivering Public Services* (London: Routledge), 7–49.
- Pang, J., Liu, X., and Huang, Q. (2020). A new quality evaluation system of soil and water conservation for sustainable agricultural development. *Agric. Water Manag.* 240:106235. doi: 10.1016/j.agwat.2020.106235
- Parry, M. L. (2019). *Climate Change and World Agriculture*. London: Routledge.
- Peng, L., Tan, J., Deng, W., and Liu, Y. (2020). Understanding the resilience of different farming strategies in coping with geo-hazards: a case study in Chongqing, China. *Int. J. Environ. Res. Public Health* 17:1226. doi: 10.3390/ijerph17041226
- Qin, C., Tang, Z., Chen, J., and Chen, X. (2020). The impact of soil and water resource conservation on agricultural production—an analysis of the agricultural production performance in Zhejiang, China. *Agric. Water Manag.* 240:106268. doi: 10.1016/j.agwat.2020.106268
- Qurniati, R., Febryano, I. G., and Zulfiani, D. (2017). How trust influence social capital to support collective action in agroforestry development? *Biodiversitas J. Biol. Diversity* 18, 1201–1206. doi: 10.13057/biodiv/d180344
- Rozaki, Z., Wijaya, O., Rahmawati, N., and Rahayu, L. (2021). Farmers' disaster mitigation strategies in Indonesia. *Rev. Agric. Sci.* 9, 178–194. doi: 10.7831/ras.9.0_178
- Sileshi, M., Kadigi, R., Mutabazi, K., and Sieber, S. (2019). Determinants for adoption of physical soil and water conservation measures by smallholder farmers in Ethiopia. *Int. Soil Water Conserv. Res.* 7, 354–361. doi: 10.1016/j.iswcr.2019.08.002
- Streletskaia, N. A., Bell, S. D., Kecinski, M., Li, T., Banerjee, S., and Palm-Forster, L. H., et al. (2020). Agricultural adoption and behavioral economics: bridging the gap. *Appl. Econ. Perspect. Policy* 42, 54–66. doi: 10.1002/aep.13006
- Takayama, T., Matsuda, H., and Nakatani, T. (2018). The determinants of collective action in irrigation management systems: evidence from rural communities in Japan. *Agric. Water Manag.* 206, 113–123. doi: 10.1016/j.agwat.2018.04.031
- Teshome, A., De Graaff, J., and Kassie, M. (2016). Household-level determinants of soil and water conservation adoption phases: evidence from North-Western Ethiopian highlands. *Environ. Manage.* 57, 620–636. doi: 10.1007/s00267-015-0635-5
- Thapa, P. S., Chaudhary, S., and Dasgupta, P. (2022). Contribution of integrated watershed management (IWM) to disaster risk reduction and community development: lessons from Nepal. *Int. J. Disaster Risk Reduct.* 76:103029. doi: 10.1016/j.ijdrr.2022.103029
- Thornton, P. K., Ericksen, P. J., Herrero, M., and Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. *Glob. Change Biol.* 20, 3313–3328. doi: 10.1111/gcb.12581
- Ullah, R., Shivakoti, G. P., and Ali, G. (2015). Factors effecting farmers' risk attitude and risk perceptions: the case of Khyber Pakhtunkhwa, Pakistan. *Int. J. Disaster Risk Reduct.* 13, 151–157. doi: 10.1016/j.ijdrr.2015.05.005
- Upadhaya, S., Arbuckle, J. G., and Schulte, L. A. (2023). Farmer typologies integrating latent and observed characteristics: insights for soil and water conservation outreach. *Land Use Policy* 134:106889. doi: 10.1016/j.landusepol.2023.106889
- VanOel, P. R., Mulatu, D. W., Odongo, V. O., Willy, D. K., and Van der Veen, A. (2019). Using data on social influence and collective action for parameterizing a geographically-explicit agent-based model for the diffusion of soil conservation efforts. *Environ. Model. Assess.* 24, 1–19. doi: 10.1007/s10666-018-9638-y
- Villamayor-Tomas, S., Thiel, A., Amblard, L., Zikos, D., and Blanco, E. (2019). Diagnosing the role of the state for local collective action: types of action situations and policy instruments. *Environ. Sci. Policy* 97, 44–57. doi: 10.1016/j.envsci.2019.03.009
- Wang, F., Mu, X., Li, R., Fleskens, L., Stringer, L. C., and Ritsema, C. J. (2015). Co-evolution of soil and water conservation policy and human-environment linkages in the Yellow River Basin since 1949. *Sci. Total Environ.* 508, 166–177. doi: 10.1016/j.scitotenv.2014.11.055
- Wang, J., Liu, L., Zhao, K., and Wen, Q. (2023). Farmers' adoption intentions of water-saving agriculture under the risks of frequent irrigation-induced landslides. *Clim. Risk Manag.* 39:100484. doi: 10.1016/j.crm.2023.100484
- Wang, Y., Li, X., Xu, Q., Ying, L., Lai, C., and Li, A. (2022). Evaluation of soil and water conservation performance under promotion incentive based on stochastic frontier function model. *Alex. Eng. J.* 61, 855–862. doi: 10.1016/j.aej.2021.04.095
- Wang, Y., Qian, X., Zhou, Y., and Chen, X. (2022). Spatial difference of Chinese public awareness of soil and water conservation and perception of information construction. *Alex. Eng. J.* 61, 8611–8623. doi: 10.1016/j.aej.2022.01.048
- Wei, C., Dong, X., Yu, D., Liu, J., Reta, G., and Zhao, W., et al. (2022). An alternative to the Grain for Green Program for soil and water conservation in the upper Huaihe River basin, China. *J. Hydrol. Reg. Stud.* 43:101180. doi: 10.1016/j.ejrh.2022.101180
- Wen, Z., and Ye, B. (2014). Analyses of mediating effects: the development of methods and models. *Adv. Psychol. Sci.* 22, 731–745. doi: 10.3724/SP.J.1042.2014.00731
- Wigboldus, S., Klerkx, L., Leeuwis, C., Schut, M., Muilerman, S., and Jochemsen, H. (2016). Systemic perspectives on scaling agricultural innovations. A review. *Agron. Sustain. Dev.* 36, 1–20. doi: 10.1007/s13593-016-0380-z
- Wordofa, M. G., Okoyo, E. N., and Erkal, E. (2020). Factors influencing adoption of improved structural soil and water conservation measures in Eastern Ethiopia. *Environ. Syst. Res.* 9, 1–11. doi: 10.1186/s40068-020-00175-4
- Xie, Y., Sarkar, A., Hossain, M. S., Hasan, A. K., and Xia, X. (2021). Determinants of farmers' confidence in agricultural production recovery during the early phases of the COVID-19 pandemic in China. *Agriculture* 11:1075. doi: 10.3390/agriculture11111075
- Yang, S., Hundloe, T., and Cramb, R. (2005). How China is adopting market mechanisms to foster soil and water conservation. *Australas. J. Environ. Manage.* 12, 37–46. doi: 10.1080/14486563.2005.10648632
- Zhang, B., Tian, L., He, C., and He, X. (2023). Response of erosive precipitation to vegetation restoration and its effect on soil and water conservation over China's Loess Plateau. *Water Resour. Res.* 59:e2022WR033382. doi: 10.1029/2022WR033382