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Green psychology: Nature and scope for sustainability

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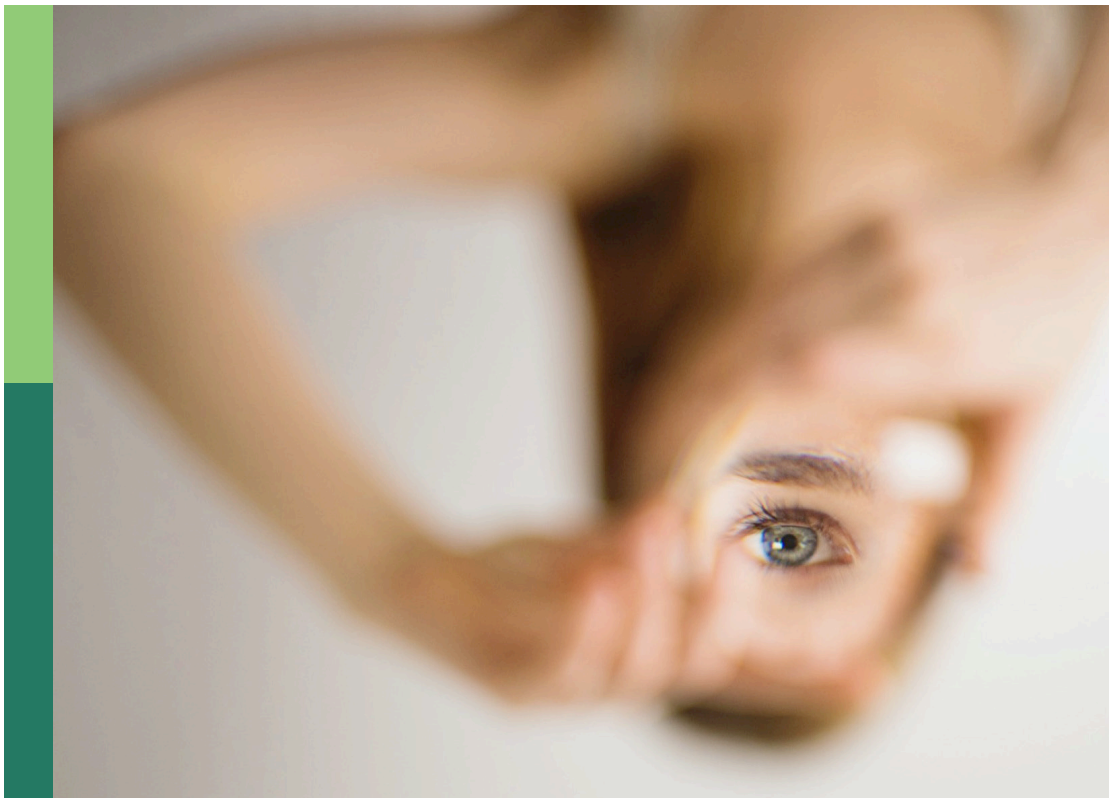

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Green psychology: Nature and scope for sustainability

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Editorial: Green psychology: nature and scope for sustainability

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KEYWORDS

green psychology, human-nature interactions, agriculture, sustainability, stakeholder perceptions

Editorial on the Research Topic
Green psychology: nature and scope for sustainability

Background

The interplay between human psychology and the natural environment has gained significant global attention in recent years. Green psychology, such as ecopsychology, is part of environmental psychology and investigates the psychological, emotional, and cognitive effects of nature on individuals and society. It explores the intricate relationship between human beings and nature, emphasizing the psychological benefits and behaviors associated with nature engagement and sustainability outcomes. Extant research has consistently shown that a stronger "human nature connection" is associated with pro-environmental attitudes, conservation and ecological awareness, adoption of sustainable lifestyle choices, and the development of an environmental identity (Klaniecki et al., 2018; Martin et al., 2020; Gansser and Reich, 2023). By recognizing and nurturing this connection, individuals can contribute and foster a sustainable future.

This special issue of articles on the Research Topic (RT) "*Green psychology: nature and scope for sustainability*" includes a good collection of research articles with an overarching objective to explore how green psychology meets the challenge of developing a sustainable society and how it can be applied to design effective interventions that promote sustainable consumption patterns. The RT sought explorations on establishing how to bridge the gap between theory and practice in green psychology-related paradigms to inform policymakers about emerging consumption trends and craft practical solutions to environmental problems. An assessment of how green psychology can contribute to the achievement of the UN Sustainable Development Goals 2030 and help create new models for sustainable behavior for individuals, organizations, and societies was expected to be a central component of such discussions in the articles. Additionally, we expected that by unveiling the emerging thought processes, emotions, beliefs, and attitudes of individuals to adopt green practices, the RT may contribute to the creation of products, services, or practices that mitigate global environmental challenges.

A synopsis of articles in the Research Topic

The articles included in this RT cover a wide variety of fields outside the specific application of theoretical concepts in many areas related to sustainability outcomes. These articles have contributed to the overall understanding of the subject matter and have advanced our knowledge in the fields of human psychology and its interface with the environment and sustainability. The call for articles has resulted in the receipt of a wide range of submissions, with a final selection of eleven original research articles prompting discussions on defining the concept of green psychology, developing models, theories, and frameworks on its influence on human behavior toward sustainability. This RT is a result of the collaboration between researchers from different parts of the world and focuses on sustainability through farmer behavior in agriculture (8 articles), citizen behavior in climate control (1 article), patient behavior in healthcare (1 article), and consumer behavior in green retail (1 article). The articles are the outcomes of research focused on many countries, such as China, Korea, Malaysia, Germany, and Iran.

As emerges from the articles, understanding the multiple stakeholder perspectives is crucial as they determine green adoption behavior. Stakeholders in a specific sustainable practice need to be motivated and educated to understand the importance of green practices and how they can contribute to sustainability. It can be related to sustainable product design or green prevention and control techniques. Sustainable design includes responsibly using materials that are recyclable or biodegradable, thus minimizing waste. Mostly, ambiguity about stakeholder or end-user emotions and tastes significantly poses challenges to sustainable design practices. The original research included in this RT by Kam and Yoo documents a design practice method to satisfy customer sensibility and individual taste in the fashion industry. The agricultural sector faces many sustainability challenges, and farmers are the most important stakeholder group willing to adopt sustainable farming methods, which are well understood as climate-resilient or climate-smart agricultural practices. In this regard, many articles in this RT address different aspects of farmer perspectives on the adoption of practices that develop sustainable outcomes. This included new technology adoption (Jia et al.), straw returning technology (Ren and Zhong), sustainable certification (Rizal and Nordin), low-carbon agricultural technologies (Jiang et al.), green control technology adoption (Chen et al.; Ren et al.), livestock manure resource utilization behavior (Gao et al.), and rangeland conservation (Savari).

The empirical studies that looked at stakeholder behavior in the adoption of sustainable practices explored several theoretical perspectives and found them relevant in the context of the studies. These include the theory of planned behavior (Ren and Zhong; Jiang et al.), rational-choice theory (Rizal and Nordin), rational behavior theory (Jiang et al.), new economic sociology theory (Ren et al.), information-motivation behavior (Chen et al.), unified theory of acceptance and use of technology (Jia et al.), and the value-belief norm (Savari). A few observations documented in this RT have policy implications. First, they suggest a cognitive process in sustainability adoptions referred to as a "prospective benefit and drawback evaluation," which involves perceived value, the level of social capital, and the level of subjective cognition (Gao et al.). Second, increasing the social capital of farmers could encourage them to embrace innovative practices (Ren et al.). Effective communication and responsible leadership are beneficial in developing a higher level of participation by smallholder farmers in sustainable practices (Rizal and Nordin). Third, the cognitive deficiencies of farmers are an important barrier to the adoption of sustainable practices, and government assistance is essential to overcome such challenges (Ren and Zhong).

The research by Song et al. examined the psychophysiological restorative potential of cancer patients through virtual reality (VR)-based perception of the natural environment and observed that blue and green hospital environments are more beneficial to psychological health compared to gray. The study established that human wellbeing is positively affected by natural environments, even among cancer patients. Similarly, Blöbaum et al. observed substantial similarities between nature conservation beliefs grounded in a biospheric value orientation (protecting biodiversity) and climate protection values and norms; there did not seem to be value-based conflicts between nature conservation and climate protection.

Looking forward: advancing green psychology research

As regards the emerging research direction, more recent policy articles and scientific studies indicate a trend toward new topics and technologies, such as carbon capture and storage (CCS), carbon capture and use (CCU), bioenergy with carbon capture and storage (BECCS), direct air carbon capture and storage (DACCS), use of hydrogen, and negative emission technologies (NETs) (Antonini et al., 2020; Borchers et al., 2022). It is important to understand the possible psychological conflicts in terms of drivers and barriers associated with these upcoming technologies, their impacts on nature and landscapes, and the eventual sustainability transformation. Further adoption and scaling up of green psychology interventions, including nature-based therapies, environmental education programs, creation of green spaces in urban environments, and ecotherapy/eco-counseling, could offer valuable approaches for promoting wellbeing, sustainable behaviors, and a deeper connection with nature. These interventions have shown promising results in enhancing mental health, fostering pro-environmental attitudes, and facilitating sustainable behaviors.

From policy perspectives, integrating green psychology into policies and practices is essential across various sectors for promoting sustainability and enhancing individuals' connection with nature. By incorporating principles of green psychology in healthcare, education, urban planning, and organizational management, it may be possible to leverage psychological insights to support pro-environmental behavior change and foster a deeper appreciation for the natural world. Such policy integrations

can contribute to a more sustainable future where policies and practices prioritize the wellbeing of both individuals and the environment.

Author contributions

MV: Writing—review and editing. VK: Writing—review and editing. GR: Writing—review and editing.

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Conflict of interest

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

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Driving mechanism of subjective cognition on farmers' adoption behavior of straw returning technology: Evidence from rice and wheat producing provinces in China

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Straw burning is one of the important causes of environmental pollution in rural China. As an important green production technology, straw returning is beneficial to the improvement of rural environment and the sustainable development of agriculture. Based on the improved planned behavior theory, taking the survey data of 788 farmers in Shandong, Henan, Hubei, and Hunan provinces as samples, this paper uses a multi-group structural equation model to explore the driving mechanism of subjective cognition on the adoption behavior of farmers' straw returning technology. The results show that behavioral attitude, subjective norm, and perceived behavioral control, which represent subjective cognition, all have significant driving effects on farmers' intention to adopt straw returning technology. Behavioral intention plays a mediating role in the process of subjective cognition driving farmers' adoption behavior of straw returning technology. Government support has a moderating role in the path from farmers' behavioral intention to behavioral response. The subjective cognition of different types of farmers has a significant driving effect on the adoption intention of straw returning technology, but the driving strength weakens with the increase of the degree of farmers' concurrent occupation. This study provides guidance for improving the government's straw returning policy and regulating straw returning behavior.

KEYWORDS

straw returning, subjective cognition, TPB, SEM, straw returning technology

Introduction

Crop straw is an agricultural biomass resource with high utilization value. According to "Development Report of China's Straw Industry in 2021," China produces about 800 million tons of straw every year (Figure 1), accounting for one-third of the global total, and the total amount of straw resources is considerable (Development Report of China's

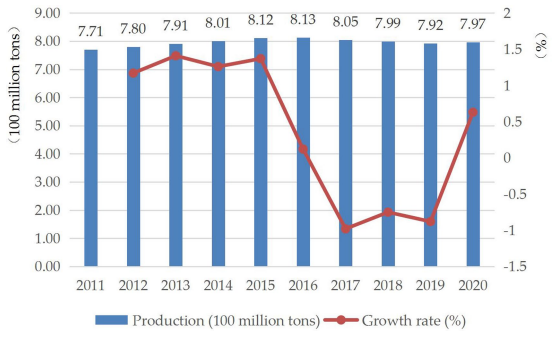

FIGURE 1
Production and growth rate of straw in China from 2011 to 2020.

Straw Industry in, 2021). For a long time, China's crop straw was mainly used for living fuel and livestock raising (Lu, 2015), but since the 1980s, with the development of economic and social transformation, the function of direct utilization of straw is gradually weakened, and open burning has become a common method of straw treatment because it is convenient and fast, and meets the time requirements of double and triple crop systems in many areas of China (Yu et al., 2017; Ren et al., 2019). However, open burning of straw will release a large amount of pollutants such as nitrogen oxides (NO_X) and sulfur oxides (SO_2) into the atmosphere, aggravating the formation of smog and harming human health (Wen et al., 2020). The haze from burning will also affect the operation of public transportation such as highways and aviation, and even cause fires, causing serious economic losses and social impacts (Jiang et al., 2019).

As a simple and low-cost conservation tillage technology, straw returning can improve soil fertility, increase crop yield, and significantly reduce the negative externalities caused by open burning of straws (Wang et al., 2012; Hou et al., 2019). It is an effective way of resource utilization of agricultural waste. Therefore, the Chinese government attaches great importance to the promotion of straw returning technology. In 2008, the State Council issued the "Opinions on Accelerating the Comprehensive Utilization of Crop Straw," which proposed to promote the technology of direct straw returning to the field by adopting operation subsidies and technical training, and adopting strict supervision and punishment measures for open burning of straw (State Council, 2008). In 2019, the Ministry of Agriculture and Rural Areas issued the "Notice on Comprehensively Utilization of Straw," emphasizing that the comprehensive utilization of straw should be accelerated nationwide (Ministry of Agriculture and Rural Areas, 2019). Regrettably, the straw returning policy has been promoted in China for many years, but with little success. Farmers have a cold attitude toward straw returning, and their enthusiasm for participation is not high. The straw burning problem has not been effectively solved (Li et al., 2018; Lu et al., 2020). Therefore, how to improve the application level of straw returning to the field and reducing the environmental pollution caused by straw burning is a major practical problem faced by the sustainable development of China's rural areas.

Farmers are the ultimate executors and direct beneficiaries of straw returning technology, and the widespread application of straw returning technology largely depends on farmers' acceptance of the technology. Therefore, it is of great significance to explore the decision-making mechanism of farmers' adoption of straw returning technology to improve the application level of straw returning to the field (Wang et al., 2022). Numerous studies have found that economic factors have an important impact on farmers' adoption behavior of straw returning technology. Huang et al. (2019) estimated through the conditional value method that the cost of farmers in Jiangsu Province, China, after adopting the straw returning technology would increase by 743 RMB/ha, and all of them would be borne by individuals, which reduced farmers' intention to adopt, and the government subsidy standard raising will help to increase farmers' intention to adopt. Yang et al. (2020) believed that the high cost and uncertain benefits of straw returning to the field are important reasons for farmers' reluctance to adopt. Hou et al. (2019) found that increasing subsidies for straw shredders can motivate farmers to adopt straw returning technology and reduce straw burning. However, economic factors are not the only factors that affect farmers' adoption of straw returning technology, and the external environment also has an important impact. Seglah et al. (2020) investigated the northern region of Ghana and found that large-scale straw burning hinders the effective use of straw resources, which is closely related to the lack of agricultural extension training and the lack of government support for prohibiting field burning of straw. Jiang et al. (2020) research findings interactions between media channels and social interactions facilitate the adoption of straw return by farmers and reinforce each other. Zheng et al. (2022) found that the use of the Internet can increase the probability of farmers adopting straw returning technology by 0.155. In addition, demographic characteristics such as education level, labor force, land scale, and income level have also been confirmed to have an important impact on the adoption of straw returning technology by farmers (Quan et al., 2011; Mao et al., 2021; Zhong et al., 2021a).

Judging from the existing research content, most of the existing research focuses on analyzing the factors affecting farmers' adoption behavior of straw returning technology from the aspects of economic factors, external environment, and demographic characteristics. These studies are based on the assumption that the objective reality faced by farmers is the basis for their behavioral decisions. However, whether or not farmers adopt the behavioral decision of straw returning technology is the best choice made under the combined influence of rational and emotional based on their subjective cognition. Their behavioral decisions are not only restricted by objective and realistic conditions, but also affected by subjective cognition formed under a specific social and cultural background (Liu and Luo, 2018), especially the aggravation of pollution caused by straw burning, which also shapes farmers' understanding of environmental problems (Lu et al., 2020). Therefore, farmers' subjective cognitive factors have attracted

more and more attention in recent years. Guo et al. (2021) analyzed that the behavioral attitude, subjective norms, perceived behavioral control, and moral responsibility of farmers have a significant positive impact on the intention to use straw resources. Li et al. (2020) found that perceived value and perceived benefit had a significant positive impact on farmers' intention to produce green agriculture, while perceived risk had a significant negative impact. Cao et al. (2020) pointed out that farmers' cognition of farmland protection policies can form subjective norms, which, in turn, guide their environmental protection agricultural practices.

In summary, the existing research has laid a good foundation and reference for this paper, but there are still some shortcomings: First, farmers' adoption behavior of straw returning technology is a decision-making process from cognition to intention to response. It is necessary to understand farmers' intention to adopt, but also to grasp the response law of converting intention into actual actions (Yan et al., 2021). Simply studying the influence of cognition on intention or behavior is difficult to grasp its inherent laws. Second, individual behavior is not only affected by intention, but also by external environmental variables such as facilitative conditions (Jeon et al., 2011). Existing studies mostly ignore the moderating role of external environmental variables in the process of converting intention into behavior. Third, existing studies generally conduct integrated research on farmers, but with the advancement of urban–rural integration in China, the continuous improvement of the degree of concurrent employment has led to the differentiation of farmers' groups (Yuan et al., 2018; Zhong et al., 2021b), and there may be differences in the influence of different types of farmers' subjective cognition in the adoption behavior of straw returning technology.

The main contributions of this paper are as follows: Firstly, based on the improved Theory of Planned Behavior, systematically explore the whole process of farmers' straw returning technology adoption behavior, so as to fully grasp the inherent law of farmers' straw returning technology adoption behavior. Secondly, the degree of concurrent employment is selected as the adjustment variable for multi-group analysis to explore the differences in the driving mechanism of straw returning technology adoption behavior by different types of farmers, so as to improve the pertinence and matching degree of policies.

This paper is organized as follows: The next section offers a conceptual frame and a number of hypotheses. It is followed by the research methods and data sources. In Section "Data analysis and empirical results," we made an empirical analysis and test. In Section "Conclusion and suggestions," we get our research conclusions and put forward policy suggestions.

Theoretical analysis and research hypothesis

Theoretical analysis

Cognitive psychology theory holds that cognition is the process by which individuals receive, process, store, and apply the acquired information. Behavioral response is a decision made by an individual based on a comprehensive analysis of his own factors and external environment based on cognitive thinking. Therefore, the generation of individual behavior depends on their cognitive ability, and different cognitive degrees will lead to different behavioral responses (Zhang et al., 2021). In order to further explore the specific influencing mechanism between cognition and behavior, this paper intends to introduce the Theory of Planned Behavior.

TPB is a modified model proposed by Ajzen based on the Theory of Reasoned Action (TRA), which is widely used to explain and predict individual behavior motivation and intention (Ajzen, 1991). The theory points out that behavioral intention is the direct factor driving behavioral response, and subjective cognition is the influencing factor driving behavioral intention. Subjective cognition can be manifested as behavioral attitude (AB), subjective norm (SN), and perceived behavioral control (PBC). Although this theory has been strongly applied in farmers' use of improved grassland (Elahi et al., 2021), use of antimicrobials prudently (Vasquez et al., 2019), adoption of integrated pest management (Rezaei et al., 2019), and adoption of animal-friendly practices (Borges et al., 2019), it only considers the influence of individual cognition on behavioral intention, and does not introduce other external socioeconomic variables, which limits the predictive power of behavioral intention to behavioral response (Cook et al., 2016). Since then, Ajzen's further research has shown that individual behavioral intention is not always successfully transformed into a behavioral response, and the process of converting intention into behavior is also affected by the external socioeconomic variables (Ajzen, 2011). Jeon et al. (2011) also pointed out that despite the strong intention, when there are obvious obstacles to hinder the behavior, the behavior cannot be easily realized, which further indicates that the external socioeconomic variables are particularly important in the process of behavior formation.

In the adoption behavior of farmers' straw returning technology, behavioral response is a rational decision made by farmers based on their cognition and evaluation of economic, environmental, risk, and other factors; understanding farmers' behavioral attitude, subjective norm, perceived behavioral control, and other cognitive constructs toward straw returning technology is a prerequisite for understanding farmers' behavioral response; and behavioral intention plays an intermediary role between subjective cognition and behavioral response. At the same time, China's straw returning technology mainly implements the government-led promotion mode. On the one hand, as a policymaker, the government's support for straw returning technology affects farmers' decision-making; On the other hand, without the government's support, which is an important external promotion condition, farmers are constrained by the cost burden and technical difficulties of straw returning, and even if they have the intention, it is difficult to translate into actual behavior response. Based on this, this paper establishes a theoretical model of improvement planning behavior, and adds the auxiliary

variable of "government support" between the behavioral intention and behavioral response of the TPB to consider the moderating effect of the external socioeconomic variable of "government support."

Research hypothesis

Behavioral attitude refers to an individual's judgment of the level of liking or disliking to perform a particular behavior. Farmers' attitudes toward the adoption of straw returning technology can be reflected by expected benefits (Meijer et al., 2015). Specifically, farmers' cognition of the expected benefits of straw returning technology can be divided into three dimensions: economy, society, and ecology. If farmers realize that straw returning technology can increase grain output, raise income level, and obtain higher economic benefits, their behavioral attitude will be more positive. If farmers realize that straw returning technology can benefit rural development, promote social progress, and produce better social benefits, their behavioral attitude will be more positive. If farmers realize that straw returning technology can improve the ecological environment, make rational use of resources, and bring positive ecological benefits, their behavioral attitude will be more positive. To sum up, this paper measures farmers' cognition of behavioral attitude in the adoption of straw returning technology from three dimensions of economic benefit, social benefit, and ecological benefit, and puts forward the following hypotheses:

> *H1*: The behavioral attitude of farmers has a direct driving effect on the adoption intention of straw returning technology.

Subjective norm refers to the external pressure that an individual perceives when deciding whether to implement a specific behavior, which reflects the influence of important individuals or groups on individual behavioral decision-making, including two dimensions: mandatory norm and exemplary norm (Cialdini et al., 1991). Mandatory norms can be understood as farmers' cognition of village cadres' advocating the adoption of straw returning technology (Yu et al., 2018). The positive encouragement and strong restraint of village cadres can prompt farmers to think "I should adopt" and "I must adopt," and then transform it into their inner intention to adopt. Exemplary norms can be understood as farmers' cognition of the adoption of straw returning technology by relatives and friends. The recognition and positive evaluation of relatives and friends will encourage farmers to have a herd mentality, and then produce a positive adoption intention. Therefore, this paper measures farmers' subjective norm cognition in the adoption of straw returning technology from two dimensions of mandatory norm and exemplary norm, and puts forward the following hypotheses:

> *H2*: The subjective norm of farmers has a direct driving effect on the adoption intention of straw returning technology.

Perceived behavioral control refers to the individual's perception of the difficulty of implementing a specific behavior, including two dimensions: self-efficacy and perceived difficulty (Kraft et al., 2005). Self-efficacy can be understood as farmers' self-confidence in the technology and cost needed to adopt straw returning behavior. Perceived difficulty can be understood as farmers' judgment on the difficulty of straw returning technology. Theoretically, the stronger the farmers' sense of self-efficacy, the less difficult it is to perceive, and the higher their enthusiasm for adopting intentions. Therefore, this paper measures farmers' perceived behavioral control in the adoption of straw returning technology from two dimensions of self-efficacy and perceived difficulty, and puts forward the following hypotheses:

> *H3*: The perceived behavioral control of farmers has a direct driving effect on the adoption intention of straw returning technology.

Behavioral intention refers to the strength of an individual's tendency to carry out a specific behavior. In farmers' adoption behavior of straw returning technology, behavioral intention refers to the subjective probability of farmers' behavioral response. Theoretically, the stronger farmers' intention to adopt straw returning technology, the more active their practical actions will be. Behavioral attitude, subjective norm, and perceived behavioral control all indirectly drive behavioral response through behavioral intention. In addition, behavioral attitude, subjective norm, and perceived behavioral control may be correlated in pairs (Zhang et al., 2021). Based on this, puts forward the following hypotheses:

> *H4*: The behavioral intention of farmers has a mediating role in the driving process of subjective cognition on the adoption of straw returning technology.
>
> *H5*: There is an interaction effect among farmers' behavioral attitude, subjective norm, and perceived behavioral control.

Government support is divided into two aspects: policy support and technical support. If farmers feel that the government supports straw returning technology through policy and shares the successful experience of other farmers' straw returning technology, and at the same time provides equipment, technical support, and related consultation and training, farmers' enthusiasm for adoption will be higher, and it will be easier for them to respond to the intention transformation behavior. Therefore, government support can help farmers who have the intention but not the ability to take it into action. Based on this, puts forward the following hypotheses:

> *H6*: Government support has a moderating role in the path from farmers' behavioral intention to behavioral response.

In summary, this study proposes a research model as shown in Figure 2.

Data, variables, and model

Data sources

The data used in this study came from questionnaires distributed by our research group in rural areas of Henan, Shandong, Hubei, and Hunan from June to August 2021. Henan and Shandong, located in the northern dry farming areas, are the main grain-producing areas of China's wheat, corn, and other agricultural products, which are suitable for popularizing the technology of "returning two crops to fields." Hubei and Hunan, located in paddy fields in the south of China, are the main rice-producing areas in China, which are suitable for popularizing the technology of returning rice straw to fields. Therefore, it is highly representative and scientific to select the above four provinces as the study areas (Figure 3).

The sample selection adopts a combination of random sampling and stratified sampling. First select two cities (counties) with large straw yield in each province, then randomly select 1–2 townships in each city (county), and then randomly select 2–3 sample villages from each township, and finally, 15–20 farmers are randomly selected from each village. Participants were explicitly informed that the questionnaire was kept confidential and that the data would be used only for research purposes. All subjects gave their informed consent for inclusion before they participated in the study. Ethical approval was obtained from the Experimental and Animal Ethics Review Board of Shandong Normal University. Face-to-face interviews were used to deeply understand the farmers and their families, subjective cognition, and straw returning adoption. A total of 840 questionnaires were distributed, 52 invalid questionnaires were excluded, and 788 valid questionnaires were obtained, with an effective rate of 93.8%.

From the perspective of sample distribution characteristics, the sample proportions of Henan, Shandong, Hubei, and Hunan are 25.1, 27.4, 22.5, and 25.0%, respectively, and the sample distribution ratios in each province are relatively close. From the perspective of individual basic characteristics, in terms of gender, male accounted for 84.6% and female accounted for 15.4%. In terms of age, farmers aged 40–60 accounted for the highest proportion (77.2%), with an average age of about 52. In terms of education level, 81.4% of the farmers' education level is junior high school or below, and the education level is generally low. In terms of annual household income, the annual income level of most farmers is below 90,000 RMB (91.2%). The main characteristics of the samples and their distribution are shown in Table 1.

Variable definition

1. Farmers' intention and behavior of straw returning technology. Referring to the research of Lu et al. (2020) and Guo et al. (2021), the adoption intention of farmers' straw returning technology is characterized from two aspects: adoption intention and promotion intention. The measurement items are based on Likert's 5-point scale, and the answer options for all questions are "very low," "lower," "average," "higher," and "very high," which are assigned "1–5," respectively. Referring to the research of Cao et al. (2020) and Srisopaporn et al. (2015), the adoption behavior of farmers' straw returning technology is characterized by two aspects: whether it is adopted or not and the intensity of adoption. Whether or not to adopt the binary valuation method, if the farmer adopts the valuation as 1, the farmer fails to adopt the valuation as 0, and the adoption intensity refers to the number of years that the farmer continuously adopts the straw returning technology.

2.Behavioral attitude, subjective norm, perceived behavioral control, and government support. The measurement items

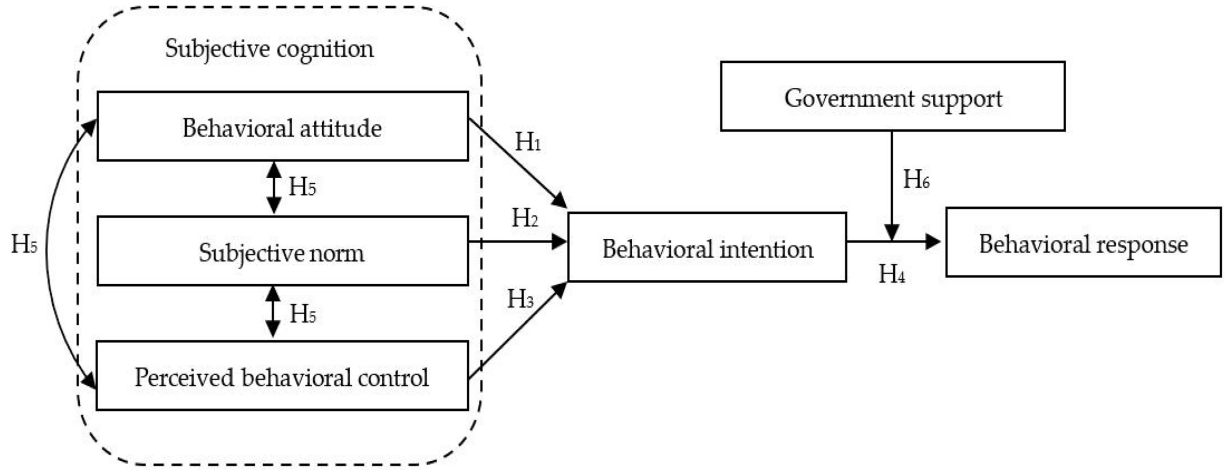

FIGURE 2
Theoretical analysis framework.

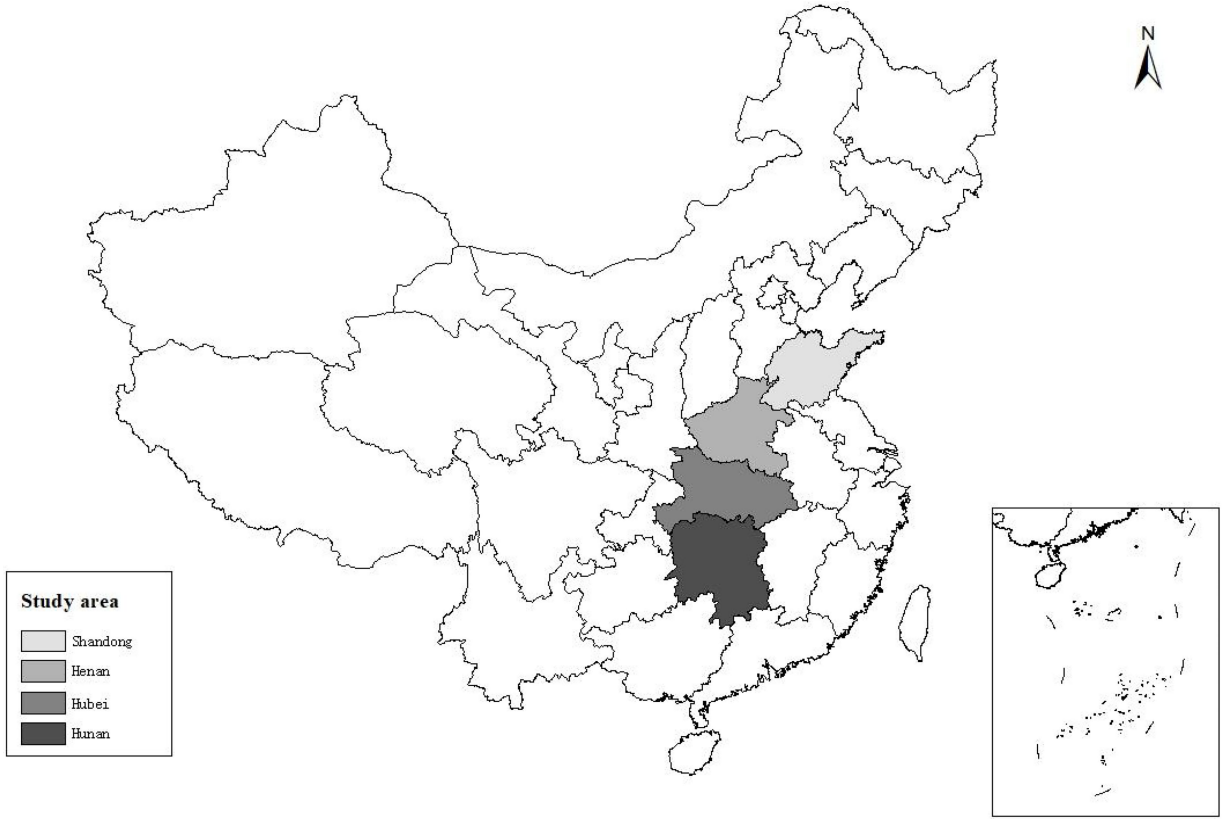

FIGURE 3
Study area.

TABLE 1 Main characteristics of the sample and its distribution.

Type	Option	Quantity	Proportion	Type	Option	Quantity	Proportion
Sex	Male	667	84.6	Education level	Primary school	215	27.3
	Female	121	15.4		Junior high school	426	54.1
Age	Under 40	76	9.6		High school	106	13.5
	40–50	263	33.4		Junior college	29	3.7
	50–60	345	43.8		University and above	12	1.4
	Over 60	104	13.2	Annual income/ million RMB	Under 3	81	10.2
Region	Henan	198	25.1		3–6	283	35.9
	Shandong	216	27.4		6–9	355	45.1
	Hubei	177	22.5		9–12	51	6.5
	Hunan	197	25.0		Over 12	18	2.3

of the four latent variables are all based on Likert's 5-scale, and the answer options of all questions are "completely disagree," "disagree," "basically agree," "comparatively agree," and "completely agree," which are assigned values of 1–5, respectively. Among them, the measurement items of behavioral attitude mainly refer to the research of Li et al. (2020), Bayard and Jolly (2007), and Luzar and Diagne (1999); the measurement items of subjective norm mainly refer to the research of Ajzen (1985) and Beedell and Rehman (2000); the measurement items of perceived behavioral control mainly refer to the research of Ajzen (1985) and Zhang et al. (2021); and the measurement items of government support mainly refer to the research of Zhang and Bin (2018) and Zhang et al. (2021). The specific definitions of variables and measurement items are shown in Table 2.

TABLE 2 Variable definition and measurement items.

Latent variable	Index	Measurement item	Source
Behavioral response (BR)	Whether to adopt	I adopted the straw returning technology (BR_1)	Cao et al. (2020), Srisopaporn et al. (2015)
	Adoption intensity	Years of continuous adoption of straw returning technology (BR_2)	
Behavioral intention (BI)	Adoption intention	The degree of my intention to adopt the straw returning technology (BI_1)	Lu et al. (2020), Guo et al. (2021)
	Promotion intention	The degree of my intention to recommend the straw returning technology to others (BI_2)	
Behavioral attitude (BA)	Economic benefits	I think straw returning technology can increase grain output and raise income level (BA_1)	Li et al. (2020), Bayard and Jolly (2007), Luzar and Diagne (1999)
	Social benefit	I think straw returning technology can conducive to rural development and social progress (BA_2)	
	Ecological benefits	I think straw returning technology can improve ecological environment and rational utilization of resources (BA_3)	
Subjective norm (SN)	Mandatory norm	Village cadres strongly advocate the adoption of straw returning technology (SN_1)	Ajzen (1985), Beedell and Rehman (2000)
	Exemplary norm	The social atmosphere of adopting straw returning technology is better (SN_2)	
Perceived behavioral control (PBC)	Self efficacy	I can master the relevant knowledge and skills (PBC_1)	Zhang et al. (2021), Ajzen (1985)
		I can bear the economic cost of straw returning technology (PBC_2)	
	Perceived difficulty	I think straw returning technology is not difficult (PBC_3)	
		I think the active adoption of straw returning technology will be successful (PBC_4)	
Government support (GS)	Policy support	Government has provided policy support for straw returning technology (GS_1)	Zhang and Bin (2018), Zhang et al. (2021)
		Government has provided share straw returning technology experience (GS_2)	
	Technical support	Government has provided equipment and technical support (GS_3)	
		Government has provided relevant consultation or training (GS_4)	

Model construction

Since the latent variables set in this paper include multiple observable variables, and some observable variables are difficult to directly observe, the Structural Equation Modeling (SEM) model as a multivariate statistical analysis method has strong adaptability. The advantage of SEM is that it can deal with multiple explanatory variables and explained variables together, and can measure the logical relationship between latent variables and observable variables (Bagheri et al., 2019a). Previous studies have shown that SEM has been widely used in the field of social science, and it is reliable and effective in explaining and predicting farmers' technology adoption behavior (Lou et al., 2021; Wang et al., 2022). As long as SEM can continuously meet the requirements of scholars, it will continue to flourish (Hershberger, 2003). Therefore, we use SEM to study. Its equation expression is as follows:

$$\eta = \beta\eta + \Gamma\xi + \zeta \tag{1}$$

$$Y = \Lambda_y\eta + \varepsilon \tag{2}$$

$$X = \Lambda_x\xi + \delta \tag{3}$$

Equation (1) is the structural equation, η is the endogenous latent variable; β is the coefficient of the endogenous latent variable η; ξ is the exogenous latent variable; Γ is the coefficient of the exogenous latent variable ξ; *and* ζ represents

the residual. Equations (2) and (3) are both measurement equations, Y and X are the observed variable vectors of the endogenous latent variable η and the exogenous latent variable ξ, respectively; *and* Λ_y and Λ_x represent the difference between Y on η and X on ξ, respectively. Correlation coefficient matrixes; ε and δ, both represent measurement errors.

Data analysis and empirical results

Normality, reliability, and validity test

1. Normality test. Maximum likelihood method is a common parameter estimation method of SEM, which requires that the data must obey multivariate normal distribution. Therefore, the skewness and kurtosis of each measurement item were analyzed by SPSS 20.0 first. The results showed that the absolute value of skewness coefficient of measurement items was between 0. 446 and 1.438, all of which were less than 3, and the absolute value of kurtosis coefficient was between 1.145 and 3.162, all of which were less than 10 (Kline, 1998). Therefore, the data of this study passed the normal distribution test.
2. Reliability test. SPSS 20.0 was used to test the overall reliability of the questionnaire and the reliability of the latent variables. The results showed that the Cronbach's α of the overall index of the questionnaire was 0.804, the Cronbach's α of the latent variables was 0.614–0.743, and the combined reliability was 0.721–0.864, both of which were greater than 0.6 (Hair et al., 2020), which indicated that the internal consistency of the latent variables was good.
3. Validity test. The validity test includes two aspects: convergent validity and discriminant validity. KMO and Bartlett's spherical test were used to analyze the convergent validity. The results showed that the calculated KMO value of the overall index of the questionnaire was 0.828, which was greater than the benchmark value of 0.7 (Zhang et al., 2020), and the Bartlett's spherical test value was equal to 4510.372, which was significant under the condition of 408 degrees of freedom. The calculated KMO values of all latent variables were greater than the benchmark value of 0.5, and the Bartlett's spherical test values of all latent variables had reached a significant level, which indicated that the data had good convergent validity. The average extracted variance value AVE and the combined reliability value CR are also used to describe the convergent validity. It is generally considered that the AVE of each factor is greater than 0.5 and the CR is greater than 0.7 (Fornell and Larcker, 1981), indicating that it has good convergent validity. As shown in Table 3, the test results all met the research needs.

Heterotrait-Monotrait Ratio (HTMT) was used to analyze the discriminant validity. Usually, the value of HTMT less than 0.85 is considered to have discriminant validity between the two variables (Henseler et al., 2015). All HTMT values (Table 4) were within the standard range, which indicated that the data had good discriminant validity.

Model fitness test

The purpose of the overall fitness test of the model is to verify whether the relationship hypothesis among the potential variables is reasonable or not, and whether the measure items of the potential variables can fully represent the comprehensive reliability of the potential variables and the research scale. In this paper, the structural equation model was fitted with Amos 24.0. According to the fitting theory of evaluation model, absolute fitting index (X^2/DF, GFI, AGFI, RMSEA, and SRMR), relative fitting index (NFI, CFI, TLI, and IFI), and reduced fitting index (PNFI, PCFI, and PGFI) were selected to analyze the fitting effect of evaluation model. The model has good fitness when the following conditions are met: X^2/DF between 1.0 and 3.0, RMSEA and SRMR should be less than 0.08, NFI, CFI, TLI, and IFI should be greater than 0.90, and PNFI, PCFI, and PGFI should be greater than 0.50 (Schreiber et al., 2006; Bagheri et al., 2019b). The results showed (Table 5) that X^2/DF = 1.563, RMSEA = 0.034, SRMR = 0.021, NFI = 0.927, CFI = 0.959, TLI = 0.946, IFI = 0.961, PNFI = 0.725, PCFI = 0.760, and PGFI = 0.701. They met the criteria, which indicated that the model had good fitness.

Structural equation model estimation result

The model calculation results show (Figure 4) that the behavior logic of farmers' straw returning technology follows the improved TPB, and the six hypotheses H1–H6 are confirmed.

1. Behavioral attitude. The behavioral attitude of farmers has a direct driving effect on the adoption intention of straw returning technology, and its path coefficient is 0.64. Among the three cognitive factors of farmers' straw returning technology adoption intention, the path coefficient is the largest, indicating that behavioral attitude is the main cognitive factor driving farmers' adoption intention of straw returning technology. Among the three observation variables of behavioral attitude, the path coefficients of economic benefit, social benefit, and ecological benefit were 0.81, 0.71, and 0.77, respectively, indicating that positive cognition of straw returning technology benefit can improve farmers' adoption intention. Compared with social and ecological benefits, farmers pay more attention to economic benefits, which is in line with economic laws, that is, as a rational economic

TABLE 3 Reliability and convergent validity test.

Latent variable	Cronbach's α coefficient	CR	AVE	KMO measure	Chi-square test	Significant level
BA	0.658	0.864	0.816	0.657	304.361	0.00
SN	0.623	0.826	0.793	0.757	747.702	0.00
PBC	0.770	0.856	0.778	0.784	1007.635	0.00
GS	0.636	0.788	0.736	0.633	110.028	0.00
BI	0.743	0.721	0.717	0.594	398.773	0.00
BR	0.614	0.793	0.792	0.617	135.447	0.00

BA, Behavioral attitude; SN, Subjective norms; PBC, Perceived behavioral control; GS, Government support; BR, Behavioral response; BI, Behavioral intention.

TABLE 4 Discriminant validity test.

	BA	SN	PBC	GS	BI	BR
BA						
SN	0.493					
PBC	0.601	0.598				
GS	0.590	0.524	0.757			
BI	0.509	0.563	0.486	0.478		
BR	0.498	0.498	0.503	0.472	0.487	

BA, Behavioral attitude; SN, Subjective norms; PBC, Perceived behavioral control; GS, Government support; BR, Behavioral response; BI, Behavioral intention.

person, the adoption of straw returning technology is a decision made by farmers based on the consideration of profit maximization.

2. Subjective norm. Farmers' subjective norm has a direct driving effect on the adoption intention of straw returning technology, and its path coefficient is 0.42. Among the three cognitive factors of farmers' straw returning technology adoption intention, the path coefficient is the smallest, indicating that subjective norm is the effective cognitive factor driving farmers' adoption intention of straw returning technology. Among the two observed variables of subjective norm, the path coefficients of mandatory norm and exemplary norm are 0.64 and 0.78, respectively, which indicates that farmers will be influenced and pressured by village cadres, relatives, and friends. In contrast, the influence from relatives and friends is greater. In rural China, family is the basic unit of production, and the contact between relatives and friends is generally greater than that with village cadres. Farmers are very concerned about their views on their production behavior, so the adoption behavior of straw returning technology by relatives and friends is more likely to stimulate farmers' herd mentality and improve their implementation intention.
3. Perceived behavioral control. Farmers' perceived behavioral control has a direct driving effect on the adoption intention of straw returning technology, and its path coefficient is 0.58. Among the three cognitive factors of farmers' straw returning technology adoption intention, the path coefficient is larger, indicating that perceived behavioral control is the important cognitive factor driving farmers' adoption intention of straw returning technology. Among the four observed variables of perceived behavioral control, the path coefficients (0.80, 0.79) of the two observed variables (PBC_3, PBC_4) representing perceived difficulty were greater than those (0.65, 0.72) of the two observed variables (PBC_1, PBC_2) representing self-efficacy, indicating that perceived difficulty plays a greater role than self-efficacy. Although straw returning technology has been promoted for many years in the surveyed areas, it has not been widely adopted by farmers. Many farmers report that due to natural conditions, technical defects, and other practical problems, straw returning is time-consuming and laborious, and it is difficult to achieve the desired effect, thus reducing the enthusiasm for adoption.
4. Behavioral intention. On the one hand, the behavioral intention of farmers has a direct driving effect on the behavioral response, and its path coefficient is 0.55, indicating that the stronger the behavioral intention is, the more likely the farmers are to adopt the straw returning technology; on the other hand, the three latent variables of subjective cognition are all through the effect of behavioral intention on farmers' adoption behavior of straw returning technology, it shows that behavioral intention plays a mediating role between subjective cognition and behavioral response.
5. The relationship between behavioral attitude, subjective norm, and perceived behavioral control. There are interaction effects among the three latent variables. The influence coefficient of behavioral attitude and subjective norm path is 0.53, indicating that the clearer the village cadre's proposition, the more obvious the demonstration of relatives and neighbors, the stronger the call and driving

force, and the more positive the behavioral attitude of farmers. Farmers' positive behavioral attitude will encourage village cadres to actively promote straw returning technology, and at the same time promote sharing and demonstration among relatives and neighbors, thus enhancing subjective norms. The influence coefficient of behavioral attitude and perceptual behavior control path is 0.46, indicating that the stronger the perceptual behavioral control of farmers over straw returning technology. The more positive the behavioral attitude of farmers, the stronger their of perception behavioral control of straw returning technology. The influence coefficient of subjective norm and perceptual behavior control path is 0.44, indicating that the stronger the farmers feel the village cadre's proposition and the demonstration of relatives and neighbors, the stronger their perceptual behavior control ability; the stronger perceptual behavior control ability of farmers, will also promote village cadres strengthen guidance and actively share with relatives and neighbors, thereby enhancing subjective norms.

6. Government support. Government support has a moderating role in the path from farmers' behavioral intention to behavioral response, and its influence

TABLE 5 Fitting results of model fitness.

Fitting index	Evaluation index	Reference value	Modified model fitting value	Test result
Absolute fitting index	X^2/DF	1.0–3.0	1.563	Ideal
	GFI	>0.90	0.976	Ideal
	AGFI	>0.90	0.972	Ideal
	RMSEA	<0.08	0.034	Ideal
	SRMR	<0.08	0.021	Ideal
Relative fitting index	NFI	>0.90	0.927	Ideal
	CFI	>0.90	0.959	Ideal
	TLI	>0.90	0.946	Ideal
	IFI	>0.90	0.961	Ideal
Reduced fitting index	PNFI	>0.50	0.725	Ideal
	PCFI	>0.50	0.760	Ideal
	PGFI	>0.50	0.701	Ideal

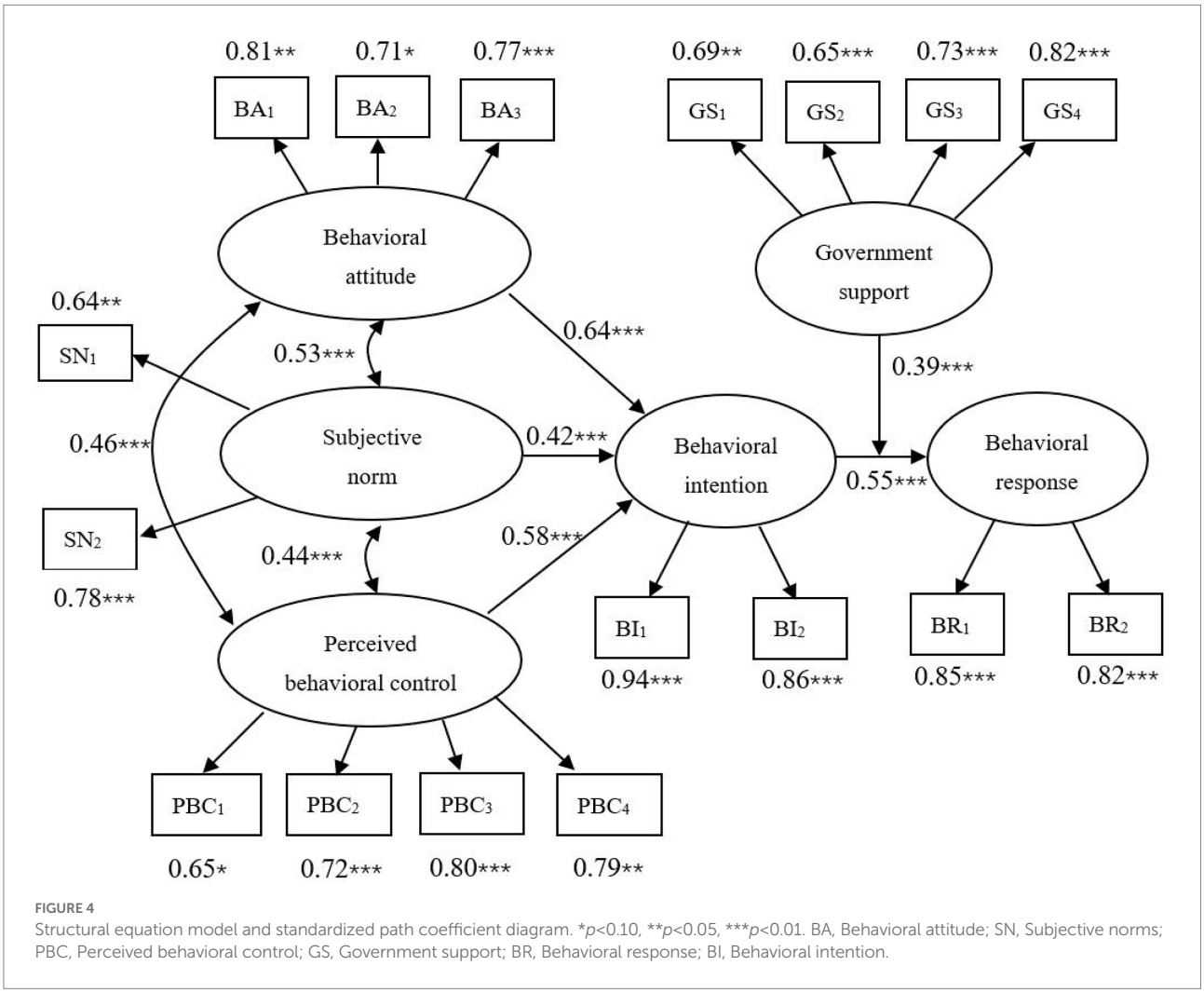

FIGURE 4
Structural equation model and standardized path coefficient diagram. *p<0.10, **p<0.05, ***p<0.01. BA, Behavioral attitude; SN, Subjective norms; PBC, Perceived behavioral control; GS, Government support; BR, Behavioral response; BI, Behavioral intention.

coefficient is 0.39, indicating that the greater the government support, the more likely the farmers' behavioral intention will be transformed into actual behavior. Among the four observation variables of government support, the path coefficients (0.73, 0.82) of the two observation variables (GS_3, GS_4) representing technical support are larger than the path coefficients (0.69, 0.65) of the two observation variables (GS_1, GS_2) representing policy support, indicating that the role of technical support is greater than that of policy support. Therefore, the effective implementation of straw returning technology needs to be equipped with professional and technical personnel to provide consulting and guidance services in each link, answer questions and doubts for farmers in time, enhance farmers' confidence in technology mastery, and promote their intention to turn into action.

Multi-group model test

In view of the heterogeneity within the farmer group, this paper uses a multi-group SEM model from the perspective of concurrent occupation to further test the differences in the driving effect of different types of farmers' subjective cognition on the adoption behavior of straw returning technology. Referring to relevant research (Liu et al., 2021), it is defined that the proportion of farmers' non-agricultural income in total household income is less than 10% as pure agricultural type, 10–50% as concurrent occupation type I, 50–90% as concurrent occupation type II, and more than 90% as non-agricultural type.

The model test results show that the maximum value of RMESA is 0.070; the minimum values of GFI, NFI, and CFI are 0.932, 0.908, and 0,944, respectively, and the *p* value of the chi-square statistic does not reach a significant level, indicating that the multi-group analysis model has a good fit with the sample data. It can be seen from Table 6 that there are similarities between the analysis results of multi-group samples and full samples: There is an interaction effect among behavioral attitude, subjective norm, and perceived behavioral control, and the three latent variables have a significant driving effect on behavioral intention; behavioral intention plays a mediating role between subjective cognition and behavioral response; government support plays a moderating role in the path from farmers' behavior intention to behavior response, that is, hypothesis H1–H6 has been verified again in different types of farmers. But there are also some differences, mainly in: (1) The driving intensity of the three latent variables on behavioral intention is significantly different among different types of farmers. The driving path coefficients of behavioral attitude to the behavioral intention of pure agriculture type, concurrent occupation type I, concurrent occupation type II, and non-agricultural type are 0.46, 0.42, 0.33, and 0.31, respectively; the drive path coefficients of subjective norm are 0.34, 0.29, 0.21, and 0.19, respectively; and the drive path coefficients of perceptual behavioral control are 0.32, 0.29, 0.28, and 0.22, respectively. This indicates that the driving effect of subjective cognition on farmers' intention to adopt straw returning technology weakens with the increase of the degree of concurrent occupation. The possible reason is that farmers with a lower degree of concurrent occupation are more dependent on land. The survey found that the pure agricultural type and concurrent occupation type I are more fully aware of the positive benefits of straw returning, have less difficulty in perceiving behavioral ability, and have stronger behavioral intention. However, farmers with a high degree of concurrent occupation mainly derive their income from non-agricultural activities, pay less attention to the productivity and sustainable utilization of cultivated land, and their behavioral intention is not high because of the awareness of the lost work caused by adopting straw returning technology. (2) Government support can prompt the four types of farmers to transform their behavioral intention into actual behavior, but the intensity of its influence gradually weakens with the increase of farmers' concurrent occupation. On the one hand, government support can effectively reduce the risk and transaction cost of farmers adopting straw returning, and provide farmers with technical and management guarantees. On the other hand, the adoption of individual behavior by farmers to return straw has risen to collective action to achieve the improvement of collective welfare, which requires the incentive and regulation of government systems and policies. Therefore, government support has a positive intervention effect on farmers' behavioral responses, but this intervention effect will gradually weaken with the reduction of farmers' holdings of agricultural production means and the weakening of their links with rural social networks.

Conclusion and suggestions

Conclusion

Guided by the improved TPB, this paper uses the multi-group SEM model to analyze the driving mechanism of subjective cognition on the adoption behavior of farmers' straw returning technology, and draws the following main conclusions:

Farmers' adoption behavior of straw returning technology follows the driving path of "cognition → intention → behavior," and three latent variables, which represent subjective cognition, such as behavioral attitude, subjective norm, and perceived behavioral control, have significant driving effects on farmers' adoption intention of straw returning technology, and behavioral intention plays a mediating role in the process of subjective cognition driving farmers' adoption behavior of straw returning technology. The driving effect of the three latent variables of subjective cognition on the farmers' straw returning technology adoption intention is behavioral attitude, perceived behavioral control, and subjective norm in descending order, and there is an interaction effect among the three. Economic

TABLE 6 Estimation results of multi-group model test.

Path	Pure agricultural type		Concurrent occupation type I		Concurrent occupation type II		Non-agricultural type	
	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
BI ← BA	0.46***	3.32	0.42***	3.67	0.33**	5.22	0.31**	4.18
BI ← SN	0.34**	3.62	0.29**	3.07	0.21*	4.25	0.19*	1.86
BI ← PBC	0.32**	2.66	0.29***	5.29	0.28**	3.74	0.22**	4.31
BR ← BI	0.43***	4.45	0.37***	3.52	0.30**	2.87	0.27*	1.64
BA ↔ SN	0.13**	1.79	0.24*	3.21	0.35***	4.93	0.37***	4.76
SN ↔ PBC	0.08*	2.86	0.16*	4.03	0.24**	5.19	0.26***	4.64
BA ↔ PBC	0.11**	2.77	0.20**	3.83	0.21**	5.84	0.26***	5.19
GS ← BI	0.43**	2.45	0.36**	3.15	0.24**	3.22	0.19**	2.74
BR ← GS	0.44***	3.02	0.38**	2.99	0.25**	3.61	0.21*	3.26

BA, Behavioral attitude; SN, Subjective norms; PBC, Perceived behavioral control; GS, Government support; BR, Behavioral response; BI, Behavioral intention.
*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$.

benefits play the largest role in behavioral attitudes, followed by ecological benefits and social benefits; the role of exemplary norm in subjective norm is greater than that of mandatory norm; the role of perceived difficulty in perceived behavior control is greater than self-efficacy. Government support plays a moderating role from farmers' behavioral intention to behavioral response, and the role of technical support is greater than that of policy support. The subjective cognition of different types of farmers has a significant driving effect on the adoption of straw returning technology, but the driving strength weakens with the increase of the degree of farmers' concurrent occupation.

Suggestions

Based on the study, this paper puts forward the following suggestions:

1. Make full use of television broadcasts, online media, publicity manuals, and other forms to increase the publicity and interpretation of relevant policies, improve farmers' awareness of economic benefits, and enhance farmers' confidence in the technical and economic prospects of straw returning.
2. Accelerate the construction of typical demonstration models, give full play to the demonstration and driving role of relatives and friends, and enable farmers to "learn by doing," and create a strong and positive social atmosphere.
3. Increase the training, guidance, and service of straw returning technology; improve the scope and standards of subsidies; ease farmers' cognition of restrictive conditions and enhance farmers' behavioral ability; and make them truly feel the economic benefits of straw returning technology.
4. The promotion of straw returning technology needs "classified and precise policy." For farmers with a low degree of concurrent occupation, they should strengthen their awareness of environmental responsibility and give further preferential policy support; for farmers with a high degree of concurrent occupation, the circulation and trusteeship of cultivated land can be encouraged to promote the effective utilization of straw.

Limitations and future research

This study also has certain limitations: Firstly, the study randomly selected four provinces in China. The scale of the study object is relatively narrow, the research results may not be directly extended to other parts of China, and the study area needs to be expanded in the future. Secondly, the study focuses on the analysis of the influence of subjective cognition on farmers' straw returning behavior, but does not cover all the factors that affect farmers' straw returning behavior, the factors need to be further supplemented in the future.

Data availability statement

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

Author contributions

ZR: writing—original draft. KZ: reviewing and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.922889/full#supplementary-material

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Smallholders participation in sustainable certification: The mediating impact of deliberative communication and responsible leadership

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The initiative to ensure oil-palm smallholders around the world participate in sustainable certification is increasing. Different efforts were strategised including increasing awareness and providing financial support. Despite that, the number of smallholders' participation in sustainable certification is relatively low. This study embarked on the objective to identify the role of social structure, namely social interaction ties in affecting smallholders' participative behaviours. Moreover, this study is also looking on the mediating impact of deliberative communication and responsible leadership in explaining the relationship between the two previously stated constructs. Using a quantitative research design, this study collected data from 440 smallholders as its respondents. Samples were randomly selected, and questionnaires were distributed to obtain their responses. Data collected were then analysed using PLS-SEM to test the developed hypothesis. Accordingly, the findings indicate that social interaction ties have a significant impact on smallholders' decisions to participate in sustainable certification. Furthermore, both deliberative communication and responsible leadership were proven to be significant mediators. This study provides insights on how smallholders' participation in sustainable certification can be improved by tapping on the social structure elements as well as adopting deliberative communication and responsible leadership as a method to communicate and lead with the smallholders. This shall expand literature related to organisation psychology in rural areas and sustainability.

KEYWORDS

social structure, communication, leadership oil-palm, sustainable farming, farmers, green psychology

Introduction

Sustainability certification has increasingly become a critical part of governance in the palm oil industry, especially in these recent years. Numerous efforts and initiatives have been spearheaded to undertake the challenges in addressing the issues raised by the public and Non-governmental Organisations. The industry is under immense pressure and

scrutiny as the key players face criticisms, especially on environmental issues. In advocating and observing sustainability, the Roundtable of Sustainable Palm Oil (RSPO) was established in 2004 to offer a platform for a voluntary act in obtaining sustainable certification. Various other similar initiatives and standards have also been established for instance the Indonesian Sustainable Palm Oil (ISPO) and Malaysian Sustainable Palm Oil (MSPO) certifications which are mandatory to producers in each level of palm oil production (Abdul Aziz and Kuntom, 2016; Shahida et al., 2019). Despite the sustainable certification initiatives, only 30% of smallholders in Malaysia have sought certification with either MSPO or RSPO.

Certification for sustainability is essential for smallholders due to several reasons. Firstly, there would be a serious threat of disruption in the palm oil supply if the global. The market only allows for palm oil products with sustainable certifications in the global value chain. Export of palm oil products to European Union (EU) markets for example has already placed a restrain on products that are considered unsustainable (Kadarusman and Pramudya, 2019), due to the pledge made by the EU countries in the Renewable Energy Directive Council (Council of the European Union, 2018). The move also echoed in the resolution of the EU's Parliament to ban palm oil by 2030 (European Parliament, 2018). This poses threats to Asian exporters like Malaysia and Indonesia (Kadarusman and Pramudya, 2019) especially when there is a huge number of smallholders who refuse to attain sustainability certifications in the country. The implication of this will affect the economy of smallholders where they would not be able to sell their products to the European market which is valued at USD 19.5 billion in 2022 and expected to grow to USD 27 billion by 2027 (Market Data Forecast, 2022). Such a huge loss will be detrimental to the livelihood of the smallholders.

Approximately 40–50% of oil palm plantations around the world are managed by smallholders with less than 5 hectares of land each (Jelsma et al., 2017; Hafizuddin-Syah et al., 2018). The rising global trade flow over the past decades provides opportunities for smallholders to participate and benefit from more commercialized global value chains (Rigg et al., 2016). Although the occasions lead to the possibility of an increase in profit and productivity amongst the smallholders, several concerns arise. First, the shift of power from farmers to processors/retailers due to the proliferation of safety and quality standards within the market create barriers to the participation of smallholders (Lee et al., 2012) that have also reduced their bargaining power. Moreover, the previous approach by institutions and government agencies that treat smallholders as a homogenous population during policy and standards development fails to adequately account for the wide range of issues faced (Jelsma et al., 2017).

From the perspective of organizational and institutional structure, smallholders form their cluster comprising several oil-palm smallholders. Together they share some of the essential resources for oil palm plantation such as knowledge, machinery and fruit dealers (Ador et al., 2016). Some even created a formal organisation in the form of cooperatives where more resources such as capital and labour are pooled together. Furthermore, revenue was shared amongst the members of organisations. Hence, it is not surprising that other institutions within the industry treat them as an organisation. For instance, in Malaysia, the authorised organisation to develop and advance the oil-palm industry – Malaysia Palm Oil Board (MPOB) created Sustainable Palm Oil Cluster (SPOC) to drive and hasten the adoption of sustainable certification by the smallholders (Ahmad Rizal et al., 2021).

Therefore, several steps were taken that mostly were aimed at increasing smallholders' awareness through extension services and training. They also provided financial support to participate in the sustainable certification scheme (Aziz et al., 2021; Majid et al., 2021). With the financial incentive and technical support provided to the smallholders in the palm oil industry, it was expected that there would be a huge number of smallholders participating in sustainable certifications. It is in accordance with the perspective of game theory and rational choice theory where an individual shall maximize their own utility when given chance to act so (Grandori, 2010; Wong, 2014; Ahmad Rizal et al., 2021). Empirical evidence however proves otherwise. However, the effort has very minimal impact on sustainability in the Malaysian palm oil industry. A study indicates that the overall sustainability score for a typical crude palm oil supply chain in Malaysia is 3.47/5, which is below the sustainability target of 5/5 (Lim and Biswas, 2019). Furthermore, approximately only 30% of the independent smallholder's plantations or about 331,740 hectares out of 986,331 hectares have obtained certification (MPOCC, 2018).

The underperformance of this initiative demands a better perspective in explaining smallholders' behaviours in adopting a sustainable certification scheme. Several studies that are looking into farmers and organisations have been suggesting other factors to explain their behaviours in adopting innovation or initiative. Nordin and colleagues in their studies (Md Nordin et al., 2021) showed that farmers sometimes look into their peer practices and observe them before making any decision. According to Bandura, human beings look into other members of society to obtain new knowledge (Bandura, 2001). Similarly, Ajzen stated that acting by society's norms affects one behaviour and attitude (Ajzen, 1991, 2020). In the organisational study, the process of sharing knowledge between members of an organization resulted in a "collective mind" which is pivotal for creating High- Reliability Organisation (HRO) (Haslam et al., 2022). In the context of this study, attention should be given to social structure where the factor could enhance the formation of collective minds which contributed to smallholders' decision to participate in sustainable certification.

The social structure itself has proven to be essential to explain individual behaviours are affected by the group's identity and norms. Studies reported that the social structure mechanism of function is affected by the production of social capital within the groups (Falk and Kilpatrick, 2000; Labianca et al., 2004). The capital comprising of trust, cooperation and coordination is produced when an individual interacts with the other individual

and the constant exchange was argued to have an effect on individual behaviours (Davis, 2014). However, the current study of sustainability behaviours and rural society is not able to explain in detail the working mechanisms of social interaction. Thus, there is a need to move beyond and explore factors that explain the mechanism of social interaction.

Researchers argue that communication and leadership are among two important elements which define the society relationship (Putnam, 1995; Gutmann, 2009; Ahmad Rizal et al., 2022). It is argued that interaction and identity development within society can only be made possible with the existence of communication and leadership. For instance, lack of communication between identity groups is proven detrimental especially when there are cultural barriers between them (Gutmann, 2009, 68). Other studies indicate that leaders could improve coordination despite the relation being separated by structural holes (detrimental factor in social structure) (Lin et al., 2001, 49). On a similar ground, these findings necessitate further probing on whether social structure elements and their impact on smallholders' participation behaviour could be explained by communication and leadership in the context of sustainability behaviour for individuals who are living and working in a group. This study looks into smallholders' participative behaviour in a sustainable scheme to explain that phenomenon.

Thus, the main objective of this study is to investigate the impact of social structure through social interaction and the mediating impact of deliberative communication and responsible leadership on smallholders' participative behaviour in sustainable certification schemes. This paper will first introduce the background of the study and followed it with a critical review of the literature. The paper will then discuss the hypothesis development, research methodology, findings and followed by a discussion and the conclusion.

The findings from this article will fill the gap in the current literature related to sustainability behaviour, and group psychology in the rural area. It will identify whether communication and leadership are proven to be factors in explaining the effect of social structure on sustainability behaviour. These findings will help the policymakers to develop a better strategic policy to increase smallholders' participation in the sustainability scheme. Moreover, it will also help the policymakers and interested groups to further understand the mechanism of sustainable behaviour amongst groups and individuals who are living in rural area.

Literature review

Overcoming rational choice theory limitation

The current literature on sustainable certification largely emphasizes rational-choice theory (RCT) to explain the lack of participation by smallholders in the schemes (Hidayat et al., 2016; Ni et al., 2016; Ahmad Rizal et al., 2021), which has its limitation. RCT primarily focuses on human behaviour in optimizing economic values and utility (i.e., personal gain or loss based on self-interest). Such assumption is often overgeneralized when explaining human actions (Hodgson, 2012). RCT is criticised for "*its excessive quest for generality, it will fail to focus on the historically and geographically specific features of the socio-economic systems that we wish to study and understand*" (Hodgson, 2012, 104). The limitation of RCT calls for consideration of another perspective to explain the low participation of smallholder farmers in sustainability schemes.

Several approaches are used to attract smallholders' participation for instance a grant for any smallholders to join the initiatives by MSPO (The Star, 2017), financial assistance certification cost (RSPO) and access to sell plantation output (i.e., Fresh Fruit Bunch, FFB) at a premium price (Johnson, 2014). These perks not only could reduce the costs but also increase the gain. Past studies argue that without such assistance, smallholders would not choose to participate in sustainability initiatives (Hidayat et al., 2016; Rietberg and Slingerland, 2016). Participation amongst smallholders is still low (MPOCC, 2018). This indicates that considerations based on RCT alone are insufficient.

By adhering to RCT, scholars and policymakers missed out on the important aspect of smallholders' livelihood that encompasses social influence and social norms. RCT puts a large focus on human behaviour based on maximizing utility (i.e., personal gain based on self-interest). Most of the empirical evidence found will always correlate with the idea of RCT, making RCT looks like a universal theory of human action (Hodgson, 2012). However, RCT lacks explanation capability and does not consider important elements such as historical, cultural and institutional specificities of particular societies in his account (Hodgson, 2012). It is therefore why economists such as Hodgson argued that RCT problems fall on "*its excessive quest for generality, it will fail to focus on the historically and geographically specific features of the socio-economic systems that we wish to study and understand*" (Hodgson, 2012, 104).

Smallholders as important stakeholders where their knowledge and practices are deeply rooted within the social culture and structures. Understanding their social structure and system is hence of paramount importance in developing a framework for heightened participation in sustainable initiatives.

Social structure as significant determinants

Smallholders, like family farmers, share a rural community social structure. Several families cluster together to form a community (Thompson, 2004). They live in a nucleus or extended family. Typically, the relationships between smallholders within a village are lateral, with informal inter-personal networks forming among the smallholders themselves (Rogers, 2003). The majority of their interactions take place in public settings, such as coffee shops, congregation halls, and community halls. A farmer's ability

to exhibit "good farming" methods to their peers determines how they are valued (Taylor and Van Grieken, 2015). In addition, they share information with other members of the group, including developments in technology and inventions to boost agricultural output and productivity (Nordin et al., 2015; Mannan et al., 2017; Ahmad Rizal et al., 2021).

Social interaction ties are the primary component of social structure. It illustrates the amount to which community members interact within the society. Interaction has been shown to be a crucial characteristic of effective social development. Adoption of innovation and implementation of the policies are correlated with strong relationships and interdependence between individual and other group members in society (Jenkins, 2014; Thévenot, 2014). Through social ties and interactions, the relationships form tight-knit cliques that are interconnected with other cliques. Individuals inside a clique are therefore linked to other cliques *via* weak relationships rather than strong ties. Nonetheless, "the strength of weak ties" is crucial for determining the extent of information dispersion in large-scale social institutions (Granovetter, 2005).

Deliberative communication: An important variable in smallholders' participation

Social structure and external environment could be the determining factors in smallholder's participation in sustainable certification as both of the factors are proven to affect knowledge dissemination. However, smallholders' participation could also be determined by rational choice. Despite these factors, other elements could be contributing to participative behaviour.

Communication is key to diffusion since it raises smallholders' awareness and competence (Rogers and Shoemaker, 1971). However, communication should involve more than a one-way approach and should consist of a regular exchange of information that consists of questions and deliberation. It is applicable either between smallholders or between smallholders and an external agency (i.e., an extension officer). Sociologists define deliberative communication as "a cohesive set of more or less coherent understandings that defines the boundaries of thought and, consequently, behaviour" (Foucault, 2002). Deliberative communication is a specific manner of shaping relationships through language and other symbolic forms (Dragoi et al., 2011). Deliberative communication is, therefore, an essential form of communication in this situation.

Deliberative communication differs from traditional instructive communication, which works its way to the traditional "informs" or "instructs" mechanism. Smallholders were needed to perform specific actions or activities based on direction and order from the authority (Ahmad Rizal et al., 2021). Whereas in deliberative communication, smallholders can challenge or argue with any of the instructions based on their knowledge or experience. In agriculture practises, particularly in developing nations, it is typical for government agencies to push farmers/smallholders to obey orders without giving them the opportunity to speak (Friederichsen et al., 2013; Pincus et al., 2018). Deliberative communication thus introduces the concept of communicative power in which judgments made by smallholders are rational and it itself is a product of the "force of better arguments" (Flynn, 2004; Allen, 2012). A study reveals that smallholders exhibit greater adaptability and comprehension of a newly introduced innovation or intervention when they are permitted to actively participate in a dialogue with the instructor, who then actively reacts to their remarks (Pincus et al., 2018).

Thus, it is important to consider deliberative communication as an essential determinant in influencing smallholder's participative behaviour to obtain sustainable certification.

Responsible leadership

Responsible leadership is a leadership concept through the Habermasian Deliberative Democracy (Voegtlin, 2016). By definition, it is associated with awareness and consideration of the consequences of one's actions for all stakeholders, as well as the exertion of influence by enabling the involvement of the affected stakeholders and by engaging in active stakeholder dialogue. Responsible leaders strive to weigh and balance the interests of the forwarded claims (Voegtlin, 2012; Ngah et al., 2022). In the case of smallholders and sustainable certification, a responsible leadership shall ensure all the relevant claims made by his or her followers either from the smallholders or other stakeholders are considered before making any decisions.

Responsible leadership has an important role during the discursive decision process. A leader shall be responsible not only for constructing the instrument to solve the problems but is also involved in the process. During the discursive decision process, a responsible leader would try to achieve consensus among the involved parties. This is achieved by weighing the arguments and balancing the interests of the stakeholders' claims. This allows leaders to "*influence through cooperation and to aim for consensual solutions, as they interact not through a supervisor-subordinate relationship but eventually with equally powerful or resource commanding entities*" (Voegtlin et al., 2012, 4). Responsible leaders, thus, represent the position and the interest of their organization (e.g., smallholders or community groups) by joining the discourse with arguments that emphasize their point of view. This definition represents an ideal of responsible leadership that can encounter restrictions in the organizational process (Stansbury, 2009; Voegtlin, 2016).

Understanding the role of leaders in the current global setting can shed light on the impact of responsible leadership on the participation of smallholders in sustainable certification. Amid the globalisation, unpredictability, and interconnectedness of the business world, good leadership must try to reduce complexity and ambiguity among its followers. Today's business leaders operate in a global, complex, uncertain, and interconnected world. Among the issues in this situation is the need to decrease

complexity and uncertainty and establish a shared vision of the future. Responsible leadership also requires the prominent leader to show various levels of accountability in executive actions and decisions for their followers (Pless, 2007). Moreover, responsible leadership generates decisions based on followers' communication and deliberation. As a result, every individual's voice matters before any decision is reached (Voegtlin, 2016). Collective responsibility and disseminating ideas among followers are fundamental to responsible leadership.

However, the essential question here is how responsible leadership can mediate the relationship? The main reason is the difference of responsible leadership with other dyadic, leader-followers hierarchical thinking of leadership. As discussed above, the key aspect of responsible leadership is the ability to develop narratives based on the emphatic experience he or she experiences in the group. The characteristic will ensure the leaders have constant dialogue and deliberative communication with the group members, hence developing an understanding of their interests. Together with a good and sustaining relationship, leaders would be able to mobilize and align the energy of different people towards achieving common objectives (Howell and Avolio, 1992; Pless, 2007).

Hypotheses and conceptual framework

Based on the literature discussed, Figure 1 shows the conceptual framework of this study. There are 3 hypotheses developed for this study:

> *H1*: Social interaction ties have a significant influence on smallholders' participative behaviour
>
> *H2*: Deliberative communication significantly mediates the relationship between social interaction ties with smallholders' participative behaviour
>
> *H3*: Responsible leadership significantly mediates the relationship between social interaction ties with smallholders' participative behaviour

Materials and methods

Research design

This section describes the constructs used in this study. All the items in the constructs utilize a 5-point Likert scale as a measurement in the survey instrument. A quantitative approach was used in this study for the data collection and analyses. This shall enable the hypotheses testing that were set earlier in the development of the research conceptual framework. The target population and unit of analysis of the study were the palm oil smallholders in Malaysia who cultivate less than forty (40) hectares. Smallholders commonly refer to landowners who are given the right to plant oil palm in their respective areas which the area should not be more than 40 hectares (Kailany, 2011; Siduque, 2015). A set of survey was disseminated amongst the smallholder farmers in Malaysia. The survey itself was adapted and adopted from the previous studies. The detail of items used in the survey is explained in the measures section.

Population and sampling

To determine the proper sampling technique, it is essential to identify the potential data analysis intended for this study. In this case, the most suitable analysis to determine the impact of constructs within an early exploratory model is Partial Linear Square–Structure Equation Modeling (PLS-SEM). Determination of sample size for this study is critical as there are cases where studies misused the advantages of PLS-SEM characteristics in analysing small sample sizes to produce the statistical output (Hair et al., 2019). The sample size in this is hence based on power analyses that consider the model structure, the anticipated significance level, and the expected effect sizes. These criteria are essential elements used by Hair and colleagues in developing their power tables known as the "minimum R-square method" to determine the proper sample size to be used in any PLS-SEM based study (Hair et al., 2017). This method, which builds on Cohen's (1992) power tables for least squares regression, relies on a table listing minimum required sample sizes based on

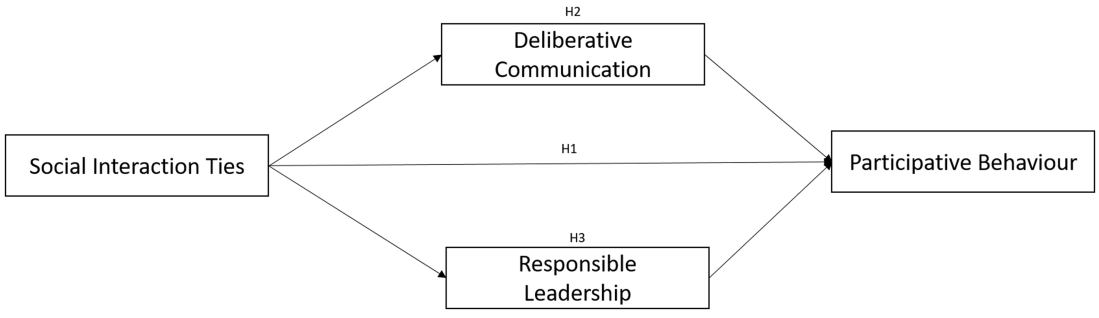

FIGURE 1
Conceptual Framework of the Study.

three elements (Kock and Hadaya, 2018). The first element of the minimum R-squared method is the maximum number of arrows pointing at a latent variable (i.e., construct) in a model. The second is the significance level used. The third is the minimum R^2 in the model.

The required sample size was based on the minimum R-square method. Since this study has 3 arrows pointing toward the latent variable (dependent variable) and seeks 1% significance with a 0.10 minimum R - squared score, 176 samples are required (Hair et al., 2019). Despite that, to increase the confidence level of the findings, 440 samples were used in this study. This research employs random sampling as its sampling technique. Potential respondents were obtained from the local MPOB office. Random number generator software was used to generate random numbers. The respondents were selected based on their associated numbers in the list matching the numbers that appeared in the software. This approach shall minimise biases in selecting the respondents.

Measures

Social interaction ties

Drawing from the study by Chiu et al. (2006), the constructs measure social relationships among smallholders. This includes their relationship in the community. The items used include, (1) I spend a lot of time interacting with members of my community, (2) I maintain close social relationships with members of my community, and (3) I have frequent engagement with members of my community.

Deliberative communication

A common communication method usually is one-directional involving orders from authority to the smallholders. This construct measures smallholders' support for rational arguments. The measures were developed by Fast (2013) and contain five items: (1) I prefer to listen to both pro and against argument in my community before deciding which one need to be supported, (2) I prefer to consider different points of views from different members of the community in any discussion, (3) Disagreement are to be expected; I believe what matters is that we continue to cooperate in deciding discussion, (4) I prefer to support a discussion that embraces any suggestions from any participant, (5) Listening to other people's view can broaden and enrich my views during the discussion.

Responsible leadership

This construct is based on instrument developed by Voegtlin (2012) and Maak et al. (2016). There are five items in the instrument: (1) I prefer leaders who demonstrate awareness of the relevant claims made by the smallholders, (2) I prefer leaders who consider the consequences of the decision for the affected smallholders, (3) I prefer leaders who include all the affected groups in the decision-making process, (4) I prefer leaders who weigh different smallholders claims before making a decision, (5) I prefer leaders who try to achieve a consensus among the affected smallholders.

Sustainability participation

Based on the instrument developed by Ni et al. (2016), this construct is to measure smallholder's participation in CSPO. The items include: (1) I actively ensure that my plantation complies with the regulation underlined in CSPO (MSPO/RSPO), (2) I will ensure my plantation always possessed CSPO (MSPO/RSPO), and (3) I actively involved during the application of CSPO certification process (MSPO/RSPO).

Data collection

This study was conducted in 2020 and 440 smallholders were involved. As stated earlier, the list of potential respondents was obtained from MPOB, Malaysia respected authority on the oil-palm commodity. Then, by using a random number generator, the respected respondent was identified. Respondents were then instructed to answer the developed questionnaire with the assistance of enumerators. The obtained data were then analysed using the PLS-SEM. To evaluate the robustness of the measurement model, reliability, convergent, and discriminant validity assessments are conducted. Then, this study's structural model was evaluated for path coefficient, predictive power, significance, and effect size. Analyses were run on SMART-PLS 3.0.

Data reporting and analysis

Firstly, data collected from this study will be analysed for demographic findings. This study then will employ Partial Least Square-Structural Equation Modelling (PLS-SEM) for inferential statistics as consequently the hypothesis testing (Hair et al., 2014; Henseler et al., 2016). The inferential analysis by using PLS-SEM can only be conducted if the measurement model, as well as the structural model validity and reliability, were assessed. Both structural and measurement models used in this study passed the assessment. Table 1 shows the score of each assessment comprising of Cronbach Alpha score for reliability analysis, composite reliability and average variance extracted (AVE) for convergent validity analysis. Additionally, the discriminant validity of this model was also determined by it Heterotrait-Monotrait (HTMT) score where each construct managed to obtain a score less than 1 indicating high discriminant validity (Ramayah et al., 2018).

Findings

Demographics

More than half of the respondents are 46 years old and above. It shows that smallholder oil palm farming is an ageing society. Similarly, the majority of the respondents (54%) have more than 15 years of experience as oil palm smallholders. Despite the

TABLE 1 Cronbach Alpha, composite reliability and average variance extraction (AVE) for each construct.

Construct	Composite reliability	Reliability (Cronbach Alpha score)	Average variance extraction (AVE)
Social Interaction Ties	0.812	0.862	0.591
Deliberative Communication	0.734	0.807	0.678
Responsible Leadership	0.781	0.812	0.737
Participative Behaviour	0.847	0.792	0.663

definition of smallholders as the farmer that operate less than 40 hectares of oil-palm plantation, the majority of respondents in this study which are 91% of total respondents operated plantation that is less than 3 hectares (3 hectares is equivalent to 7.4 acres) The details of demographic findings are shown in Table 2.

Multi-collinearity assessment

The collinearity issue is important in validating structural model integrity to avoid two sets of constructs to causally related (Ramayah et al., 2018). Collinearity is measured through variance inflation factor (VIF). A VIF value of 5 or higher indicates a potential collinearity problem (Henseler et al., 2014). All the inner VIF values of all sets of predictor constructs in the structural model are less than 5, indicating lateral multicollinearity is not a concern in the study and further examination of the model can be conducted.

Significance and relevance of the structural model relationship

Investigating the significant level and t-statistics for all paths are important in order to test the developed hypotheses which measure the impact of the relationship between constructs. Table 3 shows all the path coefficient t and *p* values for each of the relationships. To obtain the t and p values for each relationship, bootstrapping analysis by using SmartPLS 3.0 were conducted. 5,000 sub-samples were generated and the confidence interval was measured by using "Bias-Corrected and Accelerated (BCa) with two-tailed test (Hair et al., 2017). Thus, a t-value of more than 1.96 with p values <0.05 indicate a significant relationship between the two constructs (Ramayah et al., 2018). The findings indicate that social interaction ties have a significant influence on smallholders' participative behaviour. Thus, the first hypothesis of this study (H1) is accepted.

Assessment of mediation analysis

The mediation models were tested to examine the indirect effects of deliberative communication and responsible leadership on the relationship between social interaction ties, shared identity and social norms on smallholder's participative behaviour in the sustainable scheme. The bootstrapping analysis has shown that all two indirect effects are significant. There are:

- β1 = 0.329 (*t*-values = 3.615)
- β2 = 0.218 (*t*-values = 2.937)

The indirect effects 95% Boot CI Bias Corrected: β1 (LL = 0.152, UL = 0.512), β2 (LL = 0.072, UL = 0.363) show that each Upper Level (UL) and Lower Level (LL) of each relation do not straddle a 0 in between indicating there is a mediation in the

TABLE 2 Respondent profiles and demographics.

Respondent profiles	Frequency
Respondents age	
<25 years old	8
25–35 years old	82
36–45 years old	113
46–60 years old	182
>60 years old	55
Education level	
No formal education	10
Primary school	48
Secondary school	314
Post-secondary school (e.g., Technical certificate, diploma)	36
College degree (e.g., Bachelor's Degree and above)	32
Years as a smallholder	
<5 years	36
6–15 years	166
16–25 years	192
>25 years	46
Plantation size	
<1 acre	102
1–3 acre	164
3–7 acre	136
>7 acre	38

TABLE 3 Path coefficient and *p*-values for the study.

Relationship	Std beta	*p* values	Path coefficient significance
Social Interaction Ties → Participative Behavior	0.655	<0.001	Significance
Social Interaction Ties → Deliberative Communication	0.637	<0.001	Significance
Social Interaction Ties → Responsible Leadership	0.741	<0.001	Significance
Deliberative Communication → Participative Behavior	0.518	<0.001	Significance
Responsible Leadership → Participative Behavior	0.231	0.002	Significance

TABLE 4 Mediation analysis of the study.

Mediating relationship	Std beta	*p* values (significance level)
Social Interaction Ties → Deliberative Communication → Participative Behavior (β1)	0.329	<0.001**
Social Interaction Ties → Responsible Leadership → Participative Behavior (β2)	0.218	0.003**

**indicate a significant *p*-value with the rejection value of $p < 0.05$.

relationship (Preacher and Hayes, 2012; Ramayah et al., 2018). Table 4 shows the detail of the mediation analysis in the study. Findings from these analyses indicate that the second (H2) and third (H3) hypothesis of this study is accepted.

Discussion

The significance of social structure in sustainable farming psychology

The findings demonstrate that social structure component which is social interaction ties have a substantial impact on smallholders' participatory behaviour. The findings also indicated the importance of social capital, which is manifested through social interaction linkages. Smallholders collaborate closely and rely on one another for communication, information sharing, and support. In contrast to other regions of the world, primarily in the developed country, where a single individual farmer might manage dozens of hectares of land with the presence of mechanization, a plantation in Malaysia is rather operated modestly. Smallholder oil palm plantation managers often handle less than 4 hectares of land, with multiple studies indicating that the average size of a plantation is approximately that scale (Martin et al., 2015; Siduque et al., 2015; Ni et al., 2016). Social interactions have the capacity to enlarge the individual's network structure and eliminate structural gaps (Burt, 2001; Lazega et al., 2012). This feature allows information to be broadly shared and enables smallholders to have a better understanding of the sustainable certification, which in turn leads to more participatory behaviour.

The importance of social interaction as a determining factor has been demonstrated in this study. Considering smallholders in Malaysia are observed to be closely connected, social interaction has an impact on their social structure. Sociological research has long emphasised the significance of interaction. Scholars have underlined the importance of social contact in shaping and influencing human decision-making (Jenkins, 2014; Saad et al., 2017). Mamat and colleagues found that the group's development happened collaboratively in the community through a qualitative study conducted by them amongst oil palm smallholders in Pahang, Malaysia (Zufri Mamat et al., 2014). The community seeks to embrace modernization while maintaining its traditional values. This shift in cognitive viewpoint on identity among the members of the society has been demonstrated to be structural. In our study, the interaction's effect on this situation is comparable with the past study. Interaction is a key factor in a person's cognitive decision-making. Thus, in cases of sustainable certification, adopting the new policy is not totally up to a single person. This study found that living in a community created a feeling of shared identity, and a person's grasp on community interaction affected his or her decision to pursue sustainable certification.

Mediating capability of deliberative communication

This study indicated that deliberative communication mediates the relation between social interaction ties and participative behaviour. Deliberative communication refers to the concept of communicative power in which judgments made by smallholders are rational and it itself is a product of the "force of better arguments." Thus, farmers of smallholders are not simply accepting any information communicate to them, they also are able to participate actively in the communication process. This include challenging the idea and having dialogue or discussion during the process. Findings from this study is also similarly reported in other studies. For example, in a study amongst farmers in Sub-Saharan Africa, the researchers found that constant communication that focuses on developing common grounds is essential to enhance the co-learning approach amongst farmers and educators (Marinus et al., 2021). Similarly, in a study conducted in Australia, the researchers reported that having an open communication structure between farm management and farmers is essential to improve productivity, product quality and profits (Klocker et al., 2020). Both findings reaffirm our findings on the mediating capability of deliberative communication amongst smallholders.

The working mechanism is explained by the process of social interaction between actors or in this case between smallholders and other actors (e.g., smallholders, extension officers and fruit dealers). The process leads to the exchange of ideas and also a clash of beliefs. According to Habermas, social interaction leads to communication and deliberative communication emphasizes 'communicative rationality where the rational is an outcome of argument is pivotal. (Habermas, 2015). In the case of this study, deliberative communication shall first allow dual interaction between agencies involves. Hence, both of them can share and present their arguments. This ensures a non-one-way type of communication was implemented as the form of communication proven could be detrimental, especially to smallholders' awareness of new policies and issues. Furthermore, deliberative communication was shown to lead to better knowledge construction (Gastil et al., 2008). Thus, it was proven in this study that deliberative communication leads to a positive impact on smallholders' participative behaviour in sustainable certification.

Mediating capability of responsible leadership

Finding from this study indicates that responsible leadership mediate the relationship between social interactions and smallholders' participative behaviours. Responsible leadership focus on the ability of leaders to generate decisions based on followers' communication and deliberation. As a result, every individual's voice matters before any decision are reached (Voegtlin, 2016). The finding is consistent with other studies. In a study conducted amongst organic grain producers in the United States Corn Belt, the researchers identify that farmers are looking for leaders that are able to hear their concerns and suggestions in improving innovation dissemination in that area. They believe that this will strengthen the support mechanism that is much needed to propagate the process (Han et al., 2022). Furthermore, in the study amongst agro-forestry farmers, it is found that leaders who are able to create close connections with their followers will be able to enhance information sharing amongst the farmers. The information is crucial for any adoption of new methods or innovation (Lin et al., 2021).

Arguably, the mechanism of responsible leadership is related to the leaders' cognitive ability to recognize, comprehend, and reflect their interests, needs, values, and demands in a connected, complex, integrated, and balanced manner with their followers (Stahl and Sully de Luque, 2014). This cognitive ability provides the leader's resources in dealing with a wide spectrum of inquiries and attitudes of its followers. The increased amount of social interaction shall increase cognitive complexity, hence with sufficient resources, responsible leadership would be able to overcome the hindrance. Thus, leading its followers towards participation in sustainable certification. In the case of palm oil sustainable certification, not only do the leaders need to understand the behaviour and cognitive ability of their followers but there have also need to comprehend the complexity and essence of the certification itself. Failure to have that will result in an imbalance of understanding which contributed to the inability to convince his or her followers on the issues.

Furthermore, the development of responsible leadership is strongly rooted in emotional and moral experiences in the past which progressively develops from time to time (Kohlberg, 1981; Pless, 2007). The emotional and moral experience later shall develop into a sense of belonging as a product of social interaction. Hence, it is not surprising for social interaction and responsible leadership to be correlated. This is important as responsible leadership needs to understand the very fundamental struggle of its group. The situation was recorded in an empirical study conducted on paddy farmers in Perak. The farmers choose to believe their peers and colleagues for new information pertaining to innovation more than their belief in the extension officers despite the latter possess authority and better knowledge on the issue (Nordin et al., 2015). This is an example of cognitive complexity where the extension officers are unable to convey the message according to the farmers' cognitive ability. Hence, it is why responsible leadership is shown to mediate the relation between social interaction ties and participative behaviour.

Conclusion

The study examined the impact of social structure on smallholders' decision-making to participate in sustainable certification schemes. This study was motivated by limitations found in both academic literature and industrial practices. As the most productive oil seed crop, oil palm is used for both edible oil and the bio-diesel market. However, sustainability has become an issue and initiative has been taken including the introduction of sustainable certification. Despite the rigorous approaches introduced to ensure smallholders are getting certified, the results are below expectations. The study was significant in identifying the underlying factors that influence smallholders' decision to participate in the certification. Previous studies have emphasized the utility and economic dimensions while the findings from this study shed light from the social perspective taking into consideration social structure elements. Drawing on the social paradigm, this study argued that smallholders' decision-making could be explained by social interaction. Moreover, this study has also identified the mediating impact of both deliberative communication and responsible leadership on the relation between social interaction and smallholders' participative behaviour.

Thus, this study provides insights based on the scientific and validated approach to practitioners and scheme owners. It was proven in this study that social interaction, deliberative communication and responsible leadership lead to smallholders' participation in sustainable schemes. Extension officers could initiate discussions and roundtable sessions between smallholders and other smallholders or between smallholders and officers. The aim of the session is to increase social interaction and deliberative communication between smallholders. Eventually, it enhances knowledge and awareness dissemination. It is also important for scheme owners to promote non-formal discussions and increase the volume of communication as of this study show communication and social interaction are essential.

Moreover, this study also shows to practitioners that responsible leadership mediated social structure constructs. This type of leadership should be promoted not only on smallholders – leaders' relationship but also smallholders – extension officers' relationship. Extension officer's approach on smallholders is vital and it is not surprising the conventional top-down approach were consider normal practice especially involving government agencies (Redza et al., 2014). Hence, sustainability scheme owners such as MPOB could steer the leadership approach in their respective extension officers onto responsible leadership. This shall allow further enhancement in smallholders participative behaviour.

There were however several limitations in the study. A deeper analysis of social interaction between actors in the social

structure could provide some insights into the structural holes that exist in social networks when there is a lack of direct contact or tie between two or more entities (Burt, 1992). It is important to reiterate that this study and several previous studies have shown that smallholders live in clusters. It means that smallholders interact with one another creating a bunch of clusters. The clusters may be connected by an actor known as 'bridging ties' (Lin et al., 2001). However, there might be cases where there are clusters that are isolated from other clusters. Hypothetically, the isolated clusters do not receive a similar impact of social interactions which may result in a lack of access to information. This phenomenon is called structural holes. The inability of this study to investigate the effect of structural holes on smallholders' participative behaviour provides opportunities for further studies.

Future studies could possibly look on the moderating impact of structural holes. Furthermore, it could also identify which actors withing the group of smallholders has better influencing capabilities. Findings the individual capabilities shall strengthen findings of this study and further enhance the literature on social structure impact towards sustainability behaviour amongst farmers.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

SN and AR: conceptualization, methodology, and writing—original draft preparation. SN: resources and writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Practice of sustainable fashion design considering customer emotions and personal tastes

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This study aimed to determine a sustainable design practice approach that can satisfy customer emotions and personal tastes, which designers need in the early stages of the SFD process, and improve environmental performance. The research was conducted through a case study and interviews. For case studies, the specific design methods of fashion brands, which have been ranked sustainable over the last 3 years in the world's top fashion magazines favored by the public, were researched. The results of the case studies were used to draw questions for the in-depth interviews. The results are as follows: first, the design approaches of SFBs were categorized into "eco-friendly materials," "functional durability design," "reuse and remanufacturing," "emotional durability design," and sustainable fashion technology. Each type's specific design approach methods were organized into a checklist for the practice of SFD and then reflected in the interview questions. From the results of the interviews, it was noted that the sustainable design approaches perceived by Korean designers were "eco-friendly materials," "reuse and remanufacturing," and "functional durability design." Moreover, it was mentioned that specific methods of emotional durability design and sustainable fashion technology need to be acquired. By applying the checklist to the interviewees, interview participants could conveniently and quickly recognize how to apply sustainable design through the inventory. This study is significant because it presents a checklist, an efficient tool for sustainable design approaches, and a sustainable design practice method that can satisfy customer emotions and personal tastes and improve environmental performance.

KEYWORDS

sustainable fashion, sustainable design approach, sustainability, SFB, emotional durability

Introduction

The fashion industry is one of the industries that have contributed significantly to the growth of the global consumer goods industry for decades. Nevertheless, the environmental damage caused by water pollution and CO2 produced at each stage of the fashion supply chain is the second largest after the oil industry (Villemain, 2019). Hence, the fashion industry's responsibility for sustainable environmental development and its obligation to restore the environment are emphasized, as much as the share of the fashion industry in the global industry (Caniato et al., 2012; Dissanayake and Sinha, 2015; Lawless and Medvedev, 2016; Maldini et al., 2019; O'Connell, 2020). Since the mid-2000s, industrial supply systems around the world have been affected by sustainability and have struggled to develop environmental management strategies (Reoberto and Esposito, 2016). Previous studies have stated that a green supply system based on a circular economy is important in presenting a vision for sustainable manufacturing (Zhu et al., 2011; Stahel, 2016; Geissdoerfer et al., 2017). H&M has regularly published public reports on sustainability activities since it launched an ethical fashion brand called "Conscious Collection" in 2011 (Baker, 2011). In addition to mainstream brands such as Nike and M&S, it is considered a leader in sustainable business execution (Kozlowski et al., 2019; Claxton and Kent, 2020). Many fashion companies, including Uniqlo, North Face, and New Balance, also recognize the importance of sustainability and supply chain management (Shen, 2014). Early studies on sustainable fashion focused on eco-designs, which focused on the environmental harm during the product life cycle, from using materials to production and disposal. They were followed by studies on various tools for measuring performance in the three aspects of sustainability and strategies for sustainable fashion design (SFD) (Pigosso et al., 2013; Rossi et al., 2016; Ahmad et al., 2018; Karell and Niinimäki, 2020). Emotionally durable design aims at a circular economy as a design approach that extends the life of a product by encouraging a more durable and resilient relationship with the product through the emotional experience that occurs between the product and the consumer (Haines-Gadd et al., 2018). It can be said that it is a design method that allows modern people who consume selectively and wisely to choose sustainable product design according to their sensibility and personal taste. In previous studies, consumers agreed to the practice of sustainability but rejected sustainable products that did not fit their tastes (Karell and Niinimäki, 2020). Additionally, while about 80% of sustainability impacts are determined at the design stage, which is an early stage in the production process, design methods still tend to rely on the designer's intuition (Ramani et al., 2010; Ribeiro et al., 2013; Ahmad et al., 2018; Keshavarz-Ghorabaee et al., 2019; Karell and Niinimäki, 2020). Designers play an essential role in sustainable environmental performance and decisively impact the future environmental effects of their products (Boks, 2006; Ramani et al., 2010; Ribeiro et al., 2013; Ahmad et al., 2018; Keshavarz-Ghorabaee et al., 2019; Karell and Niinimäki, 2020). Nevertheless, fashion designers still need to understand the complexity of sustainable fashion issues and the unpredictable future of fashion design related to diversity, rapidly changing trends, and consumers (Kozlowski et al., 2019). The world's well-known fashion magazines, such as Vogue, Elle, and Harper's Bazaar, rank and release articles on fashion products of sustainable fashion brands (SFBs). This implies that the public interest in sustainable fashion products is high. Thus, it is imperative to propose practical methods for easy-to-use SFD, in which the complexity of sustainability and the intuition and experience of designers are objectified.

The purpose of this study is to support the circular economy by satisfying customers' sensibility and personal taste, improving environmental performance, and determining a design approach that designers can easily use in SFD.

Literature review

Sustainable fashion design

Sustainability means that businesses must address social goals such as environmental conservation, social justice, and economic development (Yıldızbaşı et al., 2021). It is in the same vein as the importance of business performance measured by considering the three dimensions of sustainability in the overall green industry (Pattnaik et al., 2021). SFD refers to design that considers the social, environmental, and economic impacts associated with the fashion products in the entire life cycle until the end of their life, from the raw materials to the use and disposal (Niinimäki, 2006; Kozlowski et al., 2019). Ecological, economic, and social factors have been the basis of many studies as the triple bottom line (TBL) of sustainability (Raza et al., 2021). Today's SFD has evolved into a system that plans products to suppress the occurrence of environmentally hazardous elements in the fashion product supply chain (Ceschin and Gaziulusoy, 2016; Kozlowski et al., 2019). In the fashion industry, three out of five apparel items are discarded within a year of production (Puspita and Chae, 2021). Problem-solving in sustainable fashion requires improving the complex apparel supply chain and the consumers, companies, and governments involved. Several previous studies have noted that designers are crucial to influencing changes in the sustainable design industry (Lawless and Medvedev, 2016; Hur and Cassidy, 2019; Kozlowski et al., 2019). To achieve the sustainability goals of fashion products, designers should play an active role in design from the early stage of the production process by predicting the ethical behavior of fashion product production and consumption (Ceschin and Gaziulusoy, 2016). For SFD, Kozlowski et al. (2019) stated that aesthetic and cultural dimensions should also be considered

along with performance in three aspects: the environmental, social, and economic aspects of sustainability. These aspects must be regarded because sustainable fashion products that have been produced so far have become another environmentally hazardous factor because they have not been chosen as consumers' tastes are not met. Currently, various tools are used to predict the performance of sustainable fashion supply chains (Bovea and Pérez-Belis, 2012; Kozlowski et al., 2019). However, considering that approximately 80% of the sustainability impact over the entire life cycle of fashion products are determined in the design stage (Ribeiro et al., 2013; Ahmad et al., 2018), it is necessary to explore various approaches to SFD.

Sustainable fashion brand

Fashion companies such as Zara, Nike, and H&M, including Kering, which currently has a portfolio of luxury brands, regularly publish public reports describing their sustainability activities (Kozlowski et al., 2019). Most sections of the fashion industry, such as general apparel, sportswear, shoes, and underwear, are paying attention to sustainable product development in consideration of environmental, economic, and social issues. In 2010, H&M announced the first sustainable collection made from sustainable materials such as organic cotton, linen, recycled polyester, and Tencel of wood pulp fabric (Portuguez, 2010). Then, in 2011, it launched a new "Conscious" collection and pledged to develop the Sustainable Apparel Coalition, an initiative devised to expand the use of organic and sustainable materials, educate cotton farmers, and measure the environment, impact, and labor practices for apparel and shoe manufacturing (Baker, 2011). In 2011, Patagonia also started the "Do Not Buy This Jacket" campaign, which promotes conscious buying, upcycling, and product use changes (Bandyopadhyay and Ray, 2020). Simultaneously, Patagonia operated a recycling program called the Common Threads Initiative, which focused on the "4 Rs" to enable the recycling of its products. It aims to reduce resale through eBay and recycling based on customer partnerships (Patagonia Inc, 2011). One of the interests of Patagonia was in ethics for the life of workers, and Patagonia became one of the first fashion brands to take responsibility in partnership with Fair Trade USA. This movement has advocated for improved social and environmental standards since 2014 (Teen Vogue, 2019; Bandyopadhyay and Ray, 2020). In 2014, to develop a roadmap to create a more sustainable supply chain and conserve endangered forests in Ho Chi Minh, Vietnam, Stella McCartney, H&M, Eileen Fisher, Patagonia, and Inditex/Zara formed a group of promising forest conservation policies. The group created a shared "knowledge map" for the viscose supply chain to facilitate the removal of endangered forest fibers and pledged to support a long-term conservation solution for high-priority forest areas, such as rainforests in Indonesia and rainforests and subarctic forests in Canada. Furthermore, they have pledged to support the development of sustainable fabric alternatives made of recycled fabrics, recycled materials, and agricultural byproducts such as straw (Sustainable brands, 2014). Stella McCartney is a London-based luxury brand belonging to Kering that does not use unsustainable animal materials, such as fur, leather, and feathers. It is known to operate a brand with ceaseless sustainable thinking. Their 2019 collection was rated as the most sustainable among the past collections because 75% of the collection used Econyl and recycled polyester, while the rest used organic cotton or upcycled denim. They announced Koba faux fur made from corn byproducts mixed with recycled polyester as an alternative to plastic options (Frost, 2019).

In 2015, Kering announced Environmental Profit and Loss (EP and L), a sustainability statement calling for industry accountability. In 2016, EP and L were applied to all brands of Kering. Further, the EP and L demanded environmental and ethical responsibility across the supply chain from damage to environmental impacts caused by fashion products and not to evade fair-trade labor practice, carbon imprint, and energy and resource conservation (Social Media Today, 2015). It started with upcycling fashion brands in 2008 and evolved as Kolon Industries, a large fashion company, launched "RE: CODE," an upcycling fashion brand that introduced fashion products manufactured by recycling fashion products to be incinerated and automotive parts (Park and Kim, 2014). RE: CODE was launched in 2012 as a sustainable brand by Kolon Industries, Inc., a large fashion company in South Korea. It creates new value based on upcycling, which refers to making new clothes by recycling deadstock and clothing waste. RE: CODE breaks fashion stereotypes, creates new uses, and encourages the world to participate in environmental and sustainable societal movements (Kolon Industries, 2012). Kolon Industries has been working on the Noah Project since 2016 as a campaign to protect endangered animals and plants in South Korea. "Kolon Sports" of Kolon Industries applied 100% eco-friendly materials and techniques to all products in the collection in 2020 as part of the Noah Project (Park, 2020).

As described above, the sustainable activities of fashion companies are group activities and campaigns focused on eco-friendly materials and material recycling. More and more fashion brands were putting the concept of sustainability at the forefront of their design goals.

Sustainable design approach and method

Previous studies have dealt with guides for various conceptual design tools and strategies to help apparel designers implement sustainability. Ceschin and Gaziulusoy (2016) classified sustainable design approaches and methods into "green design and eco-design," "emotionally durable

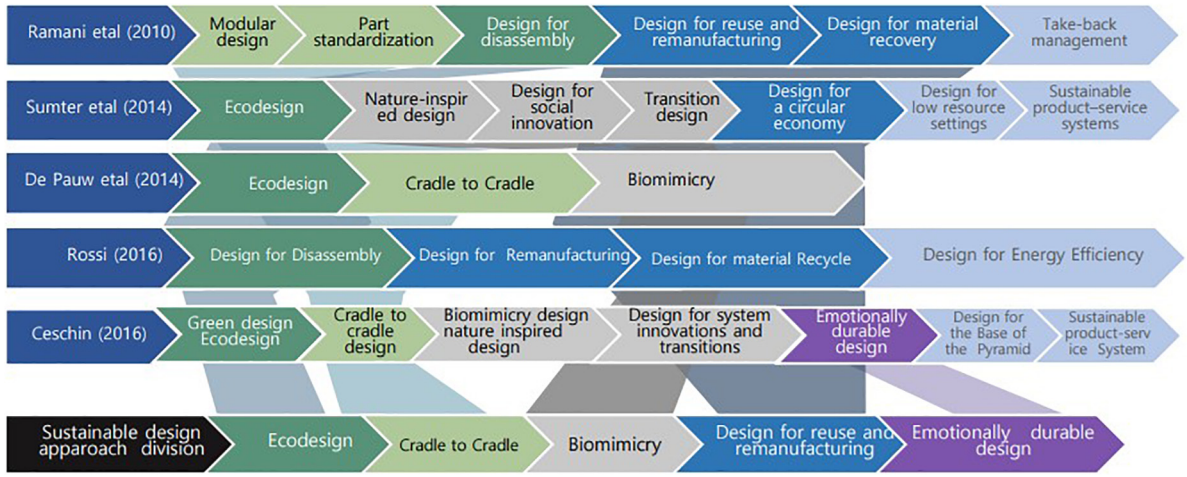

FIGURE 1
Process of classifying sustainable design approaches based on previous studies.

design," "nature-inspired design," "cradle-to-cradle design," "biomimicry design," "design for the base of the pyramid," "sustainable product-service system design," and "design for system innovations and transitions." Rossi et al. (2016) summarized design approaches with "design for X concept" and classified them into "design for disassembly," "design for remanufacturing," design for material recycling, and "design for energy efficiency." Based on some previous studies, Irwin (2015) and Sumter et al. (2020) classified design approaches by adding "design for a circular economy" to "eco-design," "nature-inspired design," "sustainable product-service systems," "design for low resource settings," "design for social innovation," and "transition design." De Pauw et al. (2014) conducted exploratory case studies to compare "eco-design" as an eco-friendly method to the methods of "biomimicry" and "cradle-to-cradle." Väänänen and Pöllänen (2020) stated that the introduction of craft techniques into recycling and upcycling products makes products aesthetically pleasing and meaningful, which can be associated with the emotional durability of products that increases consumer attachment. Attachment can be one of the solutions to these problems because sustainability products in the past have not elicited empathy for respecting the individualities and tastes of consumers, compared to the increase in environmental awareness among consumers (Karell and Niinimäki, 2020). Ramani et al. (2010) have classified "modular design," "part standardization," "take-back management," "design for disassembly," "design for reuse and remanufacturing," and "design for material recovery" as design methods for improving end-of-life (EOL) management that enables multiple life cycles of "cradle-to-cradle." Ramani et al. (2010) mentioned developing a laser-based manufacturing process to reduce material waste. Further, it involves not releasing hazardous elements during design and processes using computer-aided design (CAD) and computer-aided process planning (CAPP), which can affect the design in the early stage.

Figure 1 summarizes the classification of design approaches by researchers in previous studies. Based on these earlier studies on sustainable design, we classified design approaches into five categories in the early stage of sustainable design in this study. These include "eco-design," "cradle-to-cradle," "biomimicry," "design for reuse and remanufacturing," and "emotionally durable design," which were used in the case analysis of sustainable designs in the next section. Figure 1 shows the process of deriving five sustainable design approaches based on the classifications of the five previous studies.

Methodology

The research was conducted through a case study and interviews. The research procedure is (1) classifying sustainable design approaches through a review of previous research; (2) based on this, the sustainable design approach and detailed design method for fashion designers were investigated in the world's top fashion magazines favored by the public, (3) using the results of the case study as a tool for an in-depth interview with designers of SFB in Korea, and (4) determining design approaches that designers can easily use in the early stages of the SFD process. Figure 2 illustrates the framework of the study.

Case study

Regarding the research method, it analyzed the cases for the representation methods of SFBs that were ranked in the world's top fashion magazines based on the sustainable design

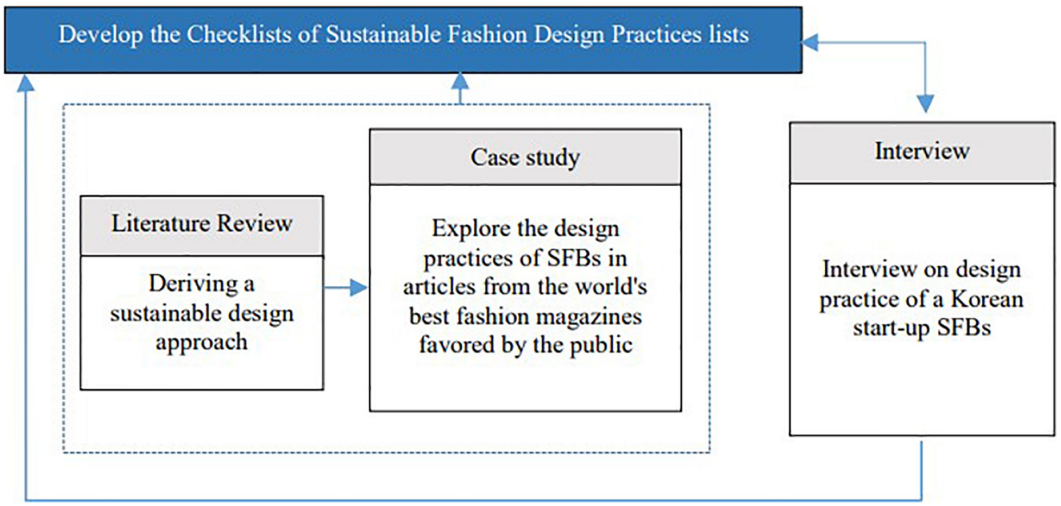

FIGURE 2
Framework of this study.

TABLE 1 Articles on sustainable fashion brands (SFBs) selected from the world's top popular fashion magazines.

Name	Year	Title of the article
Vogue	2021	11 Brands Taking Positive Steps This Earth Day
	2020	25 Sustainably-Made Goods to Recharge Your Winter Wardrobe
	2019	29 Stylish and Sustainable Pieces to Reboot Your Fall Wardrobe
Elle	2021	55 Sustainable Clothing Brands That Are Anything But Boring
	2020	24 Sustainable Clothing Brands That Are Anything But Boring
	2019	22 Eco-Friendly Brands to Shop on Earth Day
Harper's Bazaar	2021	Our favorite sustainable brands
	2020	Earth Day 2020: How Sustainable Luxury Brands Are Making a Change
	2019	How Sustainable Are These "Eco-Friendly" Fashion Brands?

approaches derived through the literature review. The analysis focused on a total of 141 SFBs in nine articles searched using "the best SFB" in Vogue, Elle, and Harper's Bazaar, which are the world's top popular fashion magazines for 3 years from 2019 to 2021. Additionally, for the analysis of the design approaches of the collected 149 SFBs, additional design methods were identified in the introduction window and product introduction of brand websites, along with the contents of the articles. Table 1 summarizes the titles of the nine articles for the top-ranking fashion brands in the analyzed fashion magazines.

TABLE 2 Interview participants.

Interview participants	Sustainable fashion branding experience (years)	Fashion designer experience (years)	Products
A	4	10	Knit, jersey wear, bag
B	6	6	Women's wear, men's wear, accessory
C	3	3	Accessory, bag, women's wear
D	4	22	Women's wear
E	4	5	Women's wear, men's wear, accessory, shoes
F	2	2	Women's wear, men's wear, cap
G	2	2	Women's wear
H	3	5	Bag, accessory, daily supplies
I	2	2	Pouch, accessory
J	2	5	Secondhand product reform, women's wear, digital cloth pattern
K	12	15	Women's wear

Interview

The interviews were conducted from 14 September 2021 to 30 March 2022. The interview participants were randomly selected from among the brands selected or applied for the

SFB support project of the Korean or local government. Eleven designers from sustainable fashion start-ups in Korea participated in the interviews. Each interview was conducted face-to-face or *via* Zoom and lasted approximately 40–50 min. **Table 2** shows the contents related to the interview participants, including Sustainable Fashion Branding Experience, Fashion Designer Experience, and fashion products designed by them. Letters were assigned according to the order of the interviews to ensure anonymity.

The interviews were recorded and transcribed with the consent of the interviewees. Semi-structured questions were used for the interview, and additional questions were asked to obtain specific answers and opinions. As shown in **Figure 3**, the interview questions were mainly composed of three questions. The first part concerned the launch date of SFB, the goal of sustainable development, and cognition of triple bottom line (TBL) of sustainability. The second part was to identify the difference between the design approach currently used by the interviewed designers and the design method shown in the world's best fashion magazines favored by the public, through the SFB design approach checklist based on the case study results. Finally, the third part consisted of comments and suggestions on practical tools for a sustainable design approach after the interview participants had used the checklist. **Figure 3** is the frame of the interview question extraction process based on the checklist derived from the case study.

Results

Case study of sustainable fashion brands' design approach

A total of 149 SFBs were ranked by the world's most popular fashion magazines for 3 years. Among them, 34 SFBs appeared twice or more, indicating that the SFB market has not yet been established stably. This may be an obvious result because it has only been approximately 10 years since fully fledged SFBs emerged. However, 35 brands were ranked only once in 2019, 19 in 2020, and 56 in 2021. Fashion brand activities were reduced in 2020 because of the SFB market shrinkage caused by COVID-19. Nevertheless, it can be seen that public interest in SFBs has increased since the number of new fashion brands in popular fashion magazines grew significantly in 2021. Thus, it is necessary to suggest a practical design approach for SFD that consumers can directly choose. **Figure 4** shows the design classification process of the SFB based on the sustainable design approach classification derived from the literature review and was used as the category for the following case study.

As a result of the case analysis based on the sustainable design approach of the previous studies, the design approaches of SFBs were categorized into: "eco-friendly materials," "functional durability design," "fashion for reuse and remanufacturing," "emotionally durable design," and "sustainable fashion technology." Furthermore, case analysis was conducted for the specific design approaches applied in the early stage of the design process of SFB based on these categories as follows:

Eco-friendly materials

The use of eco-friendly materials is one of the metrics of sustainable fashion. Specifically, as eco-friendly materials are used, the sustainability of each product increases (Wang and Shen, 2017). The environmental impact during the product life cycle can be minimized only by choosing eco-friendly materials (Ribeiro et al., 2013; Ahmad et al., 2018; Claxton and Kent, 2020). In particular, sustainable fashion products made of organic fabrics are fundamental to the supply chain because they contain fewer chemicals that harm the environment (Shen, 2014). At the initial design stage, designers should consider using biodegradable materials that can be returned to the soil without causing additional damage to nature (Gurova and Morozova, 2018).

The study of SFB product cases revealed that the selection of eco-friendly materials was required in almost all companies as a design approach. It appeared with eco-friendly materials, 100% organic cotton materials, a method tracing the origin of materials, or using vegetable materials. Additionally, it adopted a short-distance distribution to use eco-friendly materials near the production site as SFB's design strategy to reduce CO2 emissions.

1. **Certified sustainable materials using 100% organic cotton materials** include Patagonia (Nagurney and Yu, 2012), H&M Conscious (Bédat, 2019), Stella McCartney (McCartney, 2020), Mara Hoffman (Bédat, 2019), and Theory (Elle Fashion Team, 2020), Burberry (Wang, 2020), House of Sunny (Davis, 2021), BITE Studios (Elle Fashion Team, 2021), Reformation (Bédat, 2019), Baserange (Elle Fashion Team, 2021), and Yasmina Q (Davis, 2021), among others.
2. **Tracing the origin of eco-friendly materials:** Stella McCartney has adopted a method of tracing the origin of trees supplying viscose raw materials used strategically to help the environment by protecting endangered forests (Davis, 2021) and, further, including those facilitating tracing of all eco-friendly materials on the brand's website (Elle Fashion Team, 2021).
3. **Using vegetable materials:** Vegan materials include Bleusalt's signature fabric, an entirely vegan material with beech (Penrose and Hearst, 2019). Moreover, notably, Alohas made shoes with two vegan types of leather from cactus and corn (Elle Fashion Team, 2021). VEJA's sneakers used organic cotton for fair trade and soles made of rubber grown in the Amazon rainforest (Elle Fashion Team, 2021). Additionally, Allbirds often makes soles with

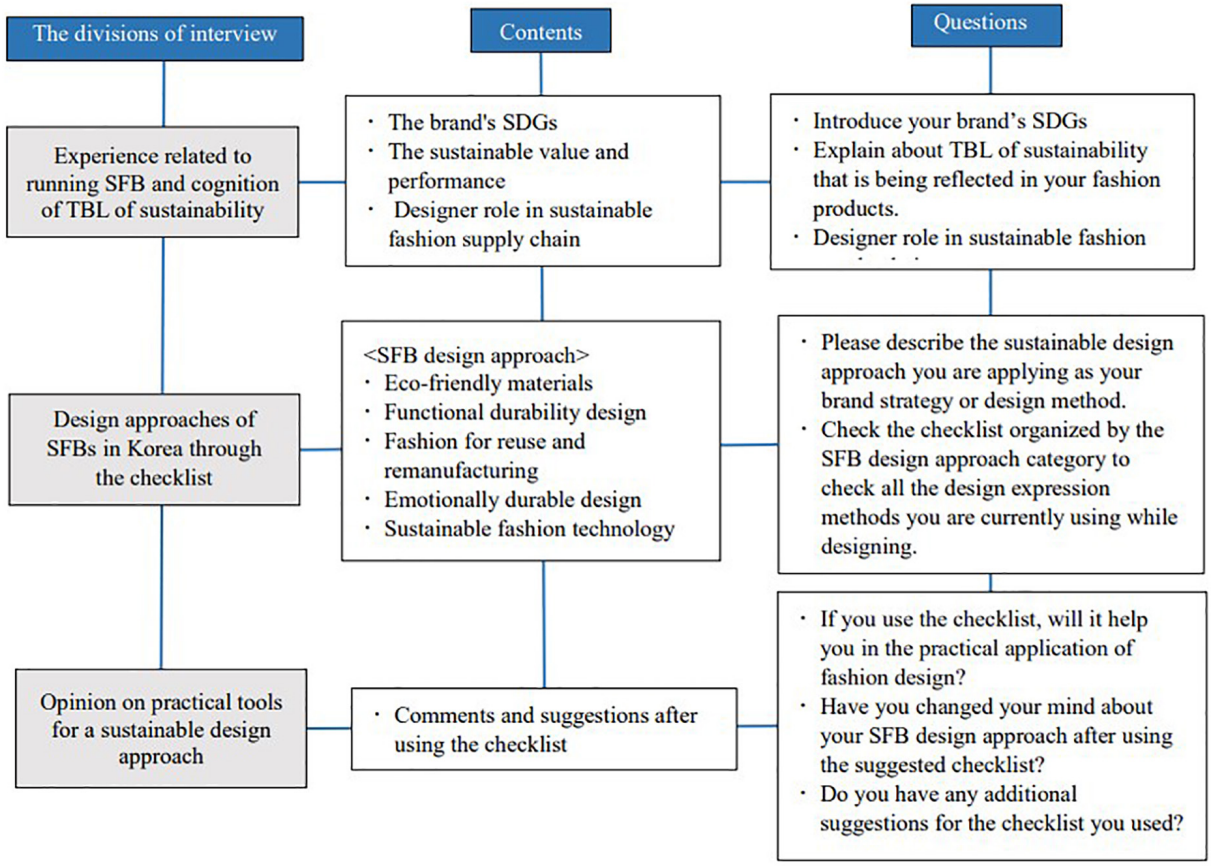

FIGURE 3
Interview questions on sustainable fashion brands' (SFBs) design approach methods.

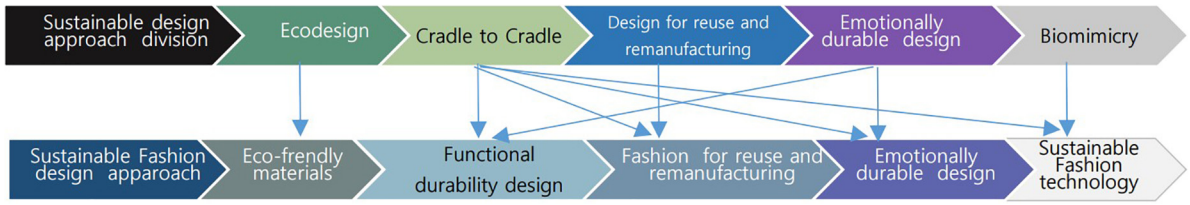

FIGURE 4
Design approach classification process of sustainable fashion brand (SFB).

sugarcane and manufacture uppers using eucalyptus or natural merino wool (Davis, 2021).

4. **Net zero:** Mulberry produces bags by developing the lowest carbon leather (Vogue, 2021). Sonia Carrasco uses only organic or vegan materials for clothes and tags, labels, packaging, and papers (Elle Fashion Team, 2021). Wright Le Chapelain maintained a transparent supply chain of sustainability and fabrics sourced from UK factories over short distances (Elle Fashion Team, 2021). Tretorn also launched eco-friendly sneakers made of locally sourced canvases (Davis, 2021).

Functional durability design

The properties and quantity of materials and the shape of the clothes used by fashion designers affect the quality and durability, which can remarkably impact the life of clothes (Claxton and Kent, 2020). Connor-Crabb et al. (2016) argued that *trans*-seasonal, multi-functionality, modularity, alterability, and physical emotional durability are approaches to functional durability design. Further, they stated that on-demand production is included in this category. According to Rahman and Gong (2016), functional durability design extends the physical life of durable, organic, and recyclable fabric

materials from a technical perspective. Moreover, it is a method of extending aesthetic life based on the emotional durability of the product. This study separated the approaches to emotional durability and discussed them. Transformable apparel provides two or more functional or aesthetic alternative styles (Rahman and Gong, 2016) and can extend the life of clothes. Modularized garment design is the task of dividing a garment into several parts based on the functional analysis of different parts. As many examples of various functions and specifications are included in each piece, user-oriented clothes can be designed quickly and flexibly (Zhou et al., 2016). According to the case study, the method of functional durability design appeared to be on-demand production, quality, durability, multi-functionality, and alterability.

1. On-demand production: The House of Sunny works on only two seasonal collections per year and produces small quantities based on orders. The design team spends more time researching sustainable fabrics, manufacturing methods, and sourcing materials (Elle Fashion Team, 2020, 2021; Davis, 2021). Further, Maison Cléo minimizes waste by selling it only once a week (Elle Fashion Team, 2020). Mary produces timeless limited editions based on orders without inventory (Elle Fashion Team, 2021).
2. Quality and durability: Everlane has chosen the finest materials and manufacturing methods for timeless products, such as the highest class cashmere sweaters, Italian shoes, and Peruvian Pima t-shirts (EVERLANE, 2021).
3. Alterability: Misha Nonoo's "Easy 8" collection features eight pieces that can produce 22 changeable looks (Davis, 2021). Nynne has included various styling options and is placed in a seam line across the leather skirt so that the length can be reduced if the user gets bored of the size and introduced reversible shearling jackets for two completely different looks (Davis, 2021). The CAES has proposed timeless items that can be worn throughout the year by adding a premium to slow fashion with a concept that compares clothes to protective "cases" that cover our bodies (Elle Fashion Team, 2021). Petit Pli designed clothes that can be worn for a long time, even if the body changes, by creating variable garments that can be increased or decreased in length depending on the wearer in a chic-pleated manner. Cho proposed varying designs with clothes that could be adjusted in size based on a detachable panel in the style of clothes manufactured using recycled plastic bottles and ethically sourced (Elle Fashion Team, 2021).

Fashion for reuse and remanufacturing

Energy is required for designing and producing new products (DeLong et al., 2014). Therefore, sustainable fashion designers should consider valuable new product design methods that facilitate multiple life cycles by reusing and reconstructing discarded products. Janigo and Wu (2015) classified design approaches for reuse and remanufacturing into repair and alteration, upcycle, downcycle, post-consumer used and secondhand clothing, post-consumer recycled clothing, and redesigned clothing. Gurova and Morozova (2018) stated that upcycling, reuse, and repurposing methods exist.

In the case study of the SFB approach, the methods of reuse and remanufacturing were sourcing sustainable yarns from waste, redesigning clothing, and repurposing.

1. Recycled yarns: Burberry heritage trench coats and lightweight classic car coats are produced using Econyl, a sustainable nylon yarn made of recycled fishing nets, fabric scraps, and industrial plastics (Wang, 2020). Baum und Pferdgarten uses recycled denim and recycled polyester from plastic bottles (Elle Fashion Team, 2021; Vogue, 2021). Maggie Marilyn sourced 100% of synthetic fibers discarded after consumption (Marius, 2020). Prada launched Prada Re-Nylon, a line of sustainable bags and accessories made of discarded cloth and recycled plastics collected from the sea and fishing nets (Elle Fashion Team, 2020). JW Anderson introduced belt totes made of recycled plastic (Elle Fashion Team, 2021). PAPER London launched swimsuits produced using recycled yarns from fishing nets, which would have taken 600 years to discompose (Elle Fashion Team, 2021). The Pringle of Scotland, known as knitwear, has used 100% recycled fibers to produce limited-edition jumpers and recycled clothing tags (Elle Fashion Team, 2021).
2. Redesigned clothing: Acne Studios has designed super-sized jackets and unique mini-skirts of modern images that the brand has as products that recycled discarded black denim and red leather (Elle Fashion Team, 2021). Rave Review introduced luxurious upcycled fashions using fabrics and deadstock clothes and created tufty overcoats by upcycling vintage bedspreads (Wang, 2020). Marine Serre has sourced discarded scarves, secondhand shirts, and wetsuit materials, turning them into futuristic practical wear from parkas to panel dresses (Lim, 2019).
3. Repurposing: Mulberry bags aim to extend product life through repair, restoration, buyback, reselling, and repurposing (Vogue, 2021). Matty Bovan sourced the fabrics and prints used in its collection by working with the Liberty Fabric Archives. In a previous collection, they recycled soccer pads to inflate the shoulders and redesigned old fur into new shapes (Bonacic, 2020).

Emotionally durable design

An emotionally durable fashion design approach can extend the product life cycle based on the emotional attachment

between consumers and products (Claxton and Kent, 2020). Emotionally durable fashion originates from a business environment in which products connect consumers and manufacturers and provide conversation pieces that facilitate the ease of upgrades, services, and repairs (Chapman, 2005). Consumers are attached to physical objects through complex interactions between cultural norms, personal preferences, and behaviors (Connor-Crabb et al., 2016). Fashion customers with a taste for handcrafted and luxurious products are emotionally attracted to secondhand clothes reborn with felt, quilt, and dye and purchase them (Janigo and Wu, 2015). Consumers stay attached for longer to products that elicit amazement and endless pleasure (Armstrong et al., 2016). Consumers' attachment to products that meet their personal characteristics and tastes leads to an extension of their product life. Design strategies that encourage social contact through sharing or group use may lead to attachment (Armstrong et al., 2016). Upcycling designs using heirlooms or garments with strong personal attachment have emotional durability (DeLong et al., 2014). Furthermore, handicrafts made by artisans have substantial value as a medium of sustainable fashion with devotion, as sustainable design reflecting local resources and culture can lead to the derivation of narratives (Sandhu, 2020).

In the study of SFBs, emotionally durable fashion designs appeared to collaborate with artisans and artists in the production area, handwoven material sourcing, and emotional design concepts.

1. Collaboration with artisans: Bite Studios creates sustainable fashion products by collaborating with emerging and existing artists in various works, such as natural dyeing techniques, printmaking, and handmade jewelry (Vogue, 2021). Chopova Lowena (Elle Fashion Team, 2021) pursues uniqueness with vibrant combinations of Bulgarian folk handcraft materials made through craftsmanship and English tailoring (Elle Fashion Team, 2020; BROWNS FASHION, 2021). Hereu's bags and shoes are products made by local artisans at the home of the founding designer of Spanish nationality (Elle Fashion Team, 2021). Ballen Pellettiere accessories commemorate Colombian fashion and artisans' crafts, and playful embroidery paired with a unique shape is a trademark of their handmade bags (Penrose and Hearst, 2019).
2. Handwoven material sourcing: Bethany Williams' recycled tents and handwoven denim ensembles reflect their signature multicolor patchwork and streetwear sentiments (Lim, 2019), while wooden buttons handcrafted by carving are discarded birches that reflect consumers' individualities and preferences (Bonačić, 2021). Bodes are brands that use recycled vintage cloth as materials and have unique handcrafted works containing stories of quilting, mending, and appliances by sourcing fabrics from all over the world, including Victorian quilts and 100-year-old linens (BODE, 2021). Brother Vellies' shoes and handbags are handmade in South Africa, Ethiopia, Kenya, and Morocco, combining the expertise of local artisans.
3. Personal design concept: Nynne approaches sustainable fashion consumer sentiment with a unique design concept named "Diana" dress as the brand's signature work (Davis, 2021).

Sustainable fashion technology

Digital tools can be used to find new behaviors in existing materials by modifying their structures, and a new understanding based on this can expand the possibilities provided to designers. By extensively using 3D design software, designers can design complex woven clothing, even if they have little understanding of weaving or weaving software (Chapman, 2005). Sustainable fashion technology is related to creative pattern cutting, which can reduce environmental impact. Zero-waste pattern cutting is making fabric using the predetermined width and length to minimize the fabric's loss in the cutting stage (Townsend and Mills, 2013). Zero-waste fashion can show new expressions while reducing or eliminating waste in product production by mixing creative design practices and zero-waste pattern cutting (McQuillan, 2019). Applying this method requires intuition and experience. However, in recent years, innovative designs and technological progress have made it easier to adopt creative practices. Software such as CLO enables fast initial design creation and facilitates the development of highly innovative woven shapes by visualizing 2D patterns, 3D shapes, and waste generated during garment design (McQuillan, 2019).

In this study, the zero-waste fashion approach also included cases in which technologies that did not affect a sustainable environment were utilized.

1. 3D technique: PRISM Squared swimwear, sportswear, underwear, and shapewear produced by a seamless 3D knitting technique are created with almost no loss of fabrics during the production process (Elle team, 2020).
2. Digital printing: Hoffman performs digital printing directly on finished sweaters to ensure that the loss of fabric caused by pattern matching will not occur (Marius, 2020; Offman, 2021).
3. Lasers and robotics: Levis produced jeans in a way that is better for the environment by combining lasers and robotics (Elle Fashion Team, 2020; Davis, 2021).

Checklist from the result of the case study

Figure 5 shows a summary of the specific methods for each design approach category, which can be applied in practical design in the early design phase of SFBs based on the

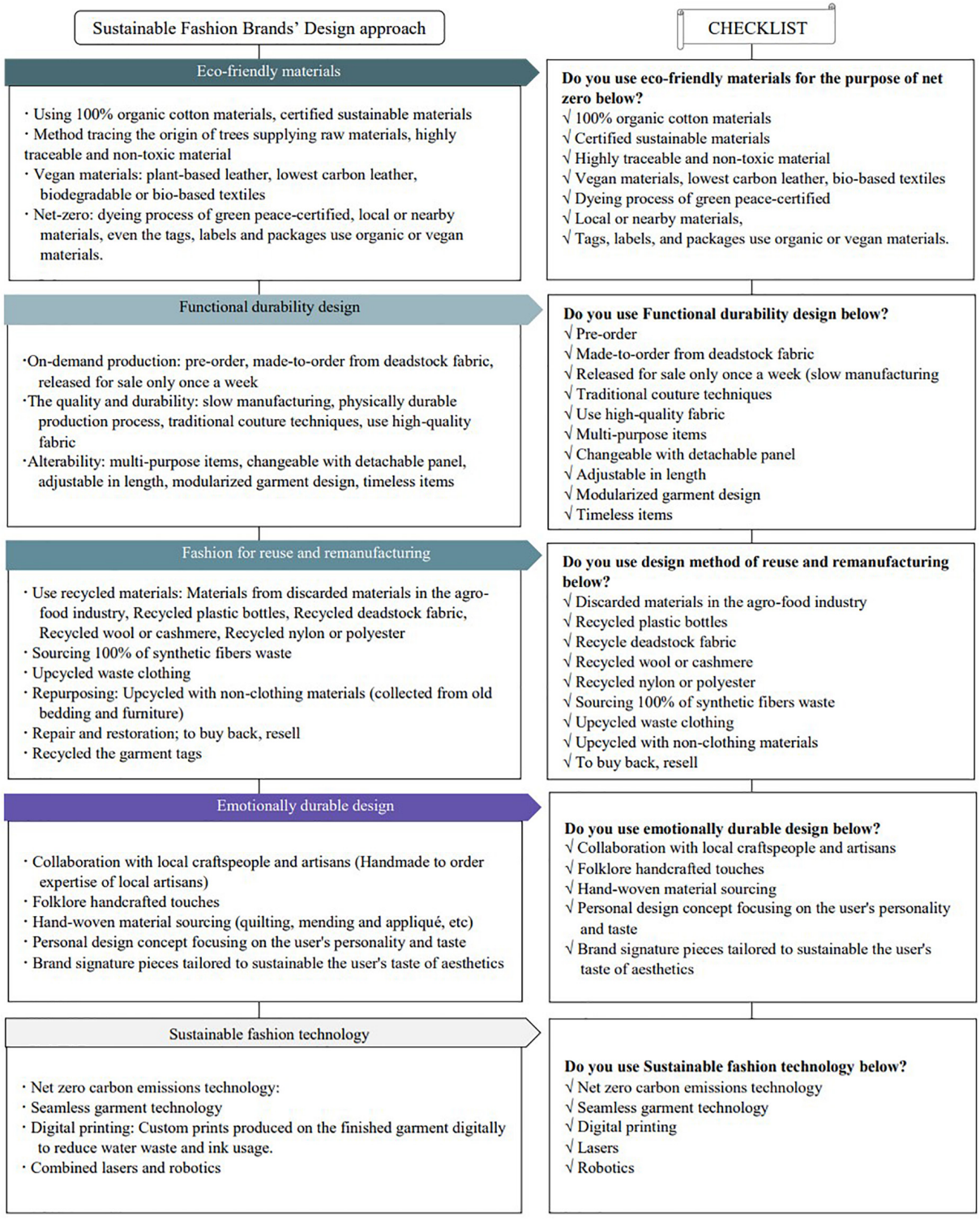

FIGURE 5
Representation methods by sustainable fashion brand (SFB) design approach category.

experimental techniques derived from the case studies for each SFD approach category.

Interview

The interview was conducted in three stages. In the first stage, questions were about fashion designers and SFB practical experience, cognitions related to TBL of sustainability, and whether and how TBL performance was applied to the company. In the second stage, an interview was conducted to find out the current practical approach of the interviewees using the SFD approach checklist derived from the SFBs case study results that appeared in the world's top popular fashion magazines. The third stage was an interview on whether the checklist can be used as a practical tool for a sustainable design approach. Eleven brands participated in interviews.

Experience related to running a sustainable fashion brand and triple bottom line of sustainability

Designers can have a significant impact on the environment by intervening early in the sustainable fashion industry supply chain. With this in mind, the first question was about knowledge of TBL and designer experience. The brands participating in the interviews ranged from micro-sized companies with one person to small- and medium-sized companies with fewer than ten employees. The duration of the SFB operation of the interviewees was between 2 and 12 years. Some of the interviewers were aware of the value and performance of the TBL of sustainability and able to properly explain the application cases in practice. The others could explain corporate SDGs, but misunderstood the TBL of sustainability. That is, most interviewees were aware of environmental values, whereas some had difficulty approaching economic and social values. In particular, they misunderstood the economic value of sustainable environmental development as the economic performance of the company. This is consistent with previous studies in which designers discussed inadequate knowledge about sustainability and the lack of time to acquire it (Knight and Jenkins, 2009; Bovea and Pérez-Belis, 2012). The results support that tools for a sustainable design approach should be designed as effective learning mechanisms.

"From the social aspect of TBL, we actively hire women who have lost their careers to provide jobs for women who can be marginalized. From an environmental point of view, the use of recycled plastic bottles was actively introduced in all of the brand's products, design, manufacturing method, and packing. We strive to reduce the impact of the environment through disposal, end-of-life treatment, which also contributes to sustainable environmental development and economic performance." (Interviewee A)

This interviewee's case was characteristic in that it aimed to expand the use of recycled plastic bottles. On the other hand, Interviewee D argued "to minimize the environmental impact, even plastic should not be used."

Interviewee A and D had opposite views of sustainable development. In the report "Synthetics Anonymous" released by the Changing Markets Foundation (2021), it is noted that downcycling plastic made from recycled plastic bottles, that is, clothing using recycled polyester, will eventually end up in landfill or incineration rather than circulating fashion. The use of PET bottles as a material for recycling is expected to be controversial in the future.

The role of designers is to create an opportunity to increase the sustainability of fashion design. Further, it is a critical change agent in sustainable fashion (Niinimäki and Hassi, 2011). Most interviewees were aware of the importance of the designer's role in attaining the value of sustainability. Interviewees A, B, C, D, and E discussed the importance of designers in reaching the value of sustainability because designers influence the life cycle of fashion products, and the design process is organically intertwined with all other areas. Interviewee I explained that a designer's sense of design determined customers' product selection and utilization. Moreover, they discussed the importance of design considering customer emotions and personal tastes to induce consumption of sustainable fashion products. Interviewees F and K stated that the role of designers is to convey the importance of sustainability to customers or boost sustainability in customer emotions and personal tastes. Through the interview results, designers can reflect on customer emotions and personal preferences in sustainable fashion products and exert influence throughout the design process to achieve sustainable goals. Designers can effectively implement sustainable fashion if there are tools that make the sustainable design approach more specific, practical, and easy to use.

Design approaches of sustainable fashion brands in Korea through the checklist

The interview on SFB's approach to sustainable design practice in Korea was conducted by presenting a checklist derived from the case analysis results in the previous chapter. As a result of participating in the checklist, the SFD approach of the brands which participated in the interview mainly utilized "eco-friendly materials," "functional durability design," and "fashion for reuse and remanufacturing." Some brands were new to or unfamiliar with the detailed expression methods of "emotionally durable design" and "sustainable fashion technology." However, it is thought that it will be helpful for the expansion of sustainable design approaches in the future by realizing that the design process that is currently being implemented for customizing consumer tastes and the design inspired by their own culture belong to this area during the interview. The "eco-friendly materials" design approach is the design approach that most interviewees used, and there were various design expression methods. For example, Interviewee B used leather

from the mulberry bark or cactus. Conversely, Interviewee D used sustainable materials, such as organic linen produced even on land unsuitable for grain production with low water consumption and pollution, and GOTS-certified organic cotton. Most of the brands interviewed chose green materials as a sustainable design approach, similar to a case study of SFB products presented by the world's leading fashion magazines that are popular with the public. However, there was no mention of a method of tracing the origin of eco-friendly materials or tracking the use of eco-friendly materials at a short distance, which is a specific design approach shown in the results of the case study.

In the case study of fashion magazines, "functional durability design" presented specific design methods such as a pre-order method without stock, quality and design that can be worn over time, high-quality sewing, and a manual showing various styling with the few fashion items. Similarly, SFBs in Korea used manual finishing and preorder on-demand methods to ensure the robustness of their products and taught them various styling methods and easy repairs.

"As a company that produces sustainable bags and clothing, it enhances the solid finish with high-quality sewing using hand-sewn in the final finishing process." (Interviewee B)

"We are adopting the slow business model as a seasonal, non-fashionable design method." (Interviewee C)

"By connecting the small-volume production method of preorder with brand membership, we create a customer group with high loyalty to the brand. This avoids unnecessary production, resulting in environmental and economic performance. It gives advice to consumers on styling when they cannot use the purchased product and provides customers with information on laundry and care. Buying well-made products from good materials will extend the lifespan of your clothes." (Interviewee K)

In the case study, "fashion for reuse and remanufacturing" was shown to be resourcing sustainable yarns from waste, or redesigning and repurposing. That is, recycled fishing nets, pieces of cloth, fabrics resourcing from plastic bottles, vintage clothing, outworn bedding, etc., were recycled and redesigned, and the original use of the material was changed. Similarly, in Korea's SFB interviews, "fashion for reuse and remanufacturing" was found to use resourced materials from waste plastic bottles, use scrap or stock fabrics, or recycle discarded clothing. Among the design expression methods shown in the case study results, most expression methods were used by the brands participating in the interviews, except for recycling waste generated in the agro-food industry as a material.

"In Korea, the domestic waste plastic bottle market is active and has been developed using various materials. So, companies who want to use it can easily purchase it." (Interviewee A)

"Among the clothes purchased from our brand, we collected the clothes the customer wanted to discard and upcycled it in the direction the customer wanted. The customer liked it very much." (Interviewee K)

"We are producing hand-knitted handbags by collecting materials thrown away during the clothing-making process." (Interviewee G)

"The main item is a fabric book cover, and the direction of our brand is to collect discarded scraps and waste subsidiary materials and recreate them as marketable products using handicraft techniques." (Interviewee I)

"We produce and provide digital patterns that are used to remodel used clothing and provide tutorials for redesigning used clothes into clothing and accessories." (Interviewer J)

In some cases, wastes with poor function for sports or leisure were recycled and developed into clothing.

"Leisure sports materials such as paragliding, glamping, tents, sails which have been destroyed for safety reasons, but have no problem in actual use, are collected, dismantled, washed, and recycled through a series of processes such as cutting and sewing." (Interviewer H)

As mentioned above, the approaches of "emotionally durable design" and "sustainable fashion technology" were utilized in conjunction with "functional durability design" or "fashion for reuse and remanufacturing."

"Emotionally durable design" was a method recognized and applied by only a small number of brands participating in the interview. Interviewee E understood that this design approach is sustainable after checking the design approach of "emotionally durable design" in the checklist.

The specific method of "emotionally durable design" shown in the case study was collaboration with local craftspeople and artisans, folklore handcrafted touches, handwoven material sourcing, personal design concept focusing on the user's personality and taste, and brand signature pieces.

In Korea's SFB interviews, "emotionally durable design" appeared as an inspirational approach to handicrafts such as knitting, quilting, and traditional elements of Korea.

"Through work that mixes handicraft with everyday products, we want to appeal to consumers' sensibility and emphasize to consumers that everything from cutting to finishing is done manually." (Interviewer I)

"Because we produce products using the preorder method of "Saekdong," a traditional Korean element, as our brand signature item, we can reflect the individuality and taste of consumers." (Interviewer E)

"Sustainable fashion technology" is the design approach adopted the least by the brands that participated in the interview. Although it was recognized as a sustainable design approach, designers faced barriers. This was consistent with a previous study, establishing that designers are limited in their adoption of tools for sustainable design or are unable to use them because they are unaware of their existence (Kozlowski et al., 2019). Among the brands that participated in the interview, Interviewees A and B, whose company size was large,

actively used seamless 3D knitting techniques, digital printing, and laser cutting technology for finished fashion products but did not mention robotic technology.

"We know that digital printing technology is a sustainable fashion technology, but it is economically burdensome for our head office to have digital printers." (Interviewee F)

"Our brand also produces knits and jerseys; thus, we know 3D knitting is a comfortable and sustainable way to wear it, but do not know how to approach it." (Interviewee G)

"Sustainable fashion technology" had a high barrier for interview participants to approach. This is because the size of the brands participating in the interview was small. Notwithstanding, considering that the scale of SFBs is small- and medium-sized, sustainable fashion technology is a sustainable design approach that requires active support or investment from the government.

Opinion on practical tools for sustainable fashion design approach

After using the suggested checklist, interviewees were asked for their opinions and suggestions on the checklist as a practical tool. Regarding the advantages of using the inventory, the interviewees stated that the checklist, a valuable tool for a sustainable design approach, can help clarify a brand's strategy and easily learn sustainable design approaches. This is considered a tool that can overcome the barriers and limitations of the sustainable design approach. Additionally, they stated that the direction of the sustainability concept could be identified more clearly if the checklist was used when establishing a sustainable brand strategy or planning a new product that pursues sustainability.

"The checklist provides guidelines for SFD. I thought it existed only in theory, but if I checked it when making a product, one could address the missing parts. Furthermore, sustainable brands pursue different goals. It is helpful to think about which side we focus on and value more." (Interviewee C)

"It is an opportunity to check the brand design direction once more while checking the checklist." (Interviewee F)

"I think I can check the brand concept by looking at this checklist when doing a new project." (Interviewee H)

They said learning new sustainable design expression methods is also an advantage.

"While going over the checklist, I thought sustainability could be expressed this way. If we focus on what we are doing in practice, there would be insufficient time to review other things. Thus, the checklist can enable easy and quick understanding." (Interviewee B)

"I was worried about not practicing it or overlooking it because of ignorance. If there is a tool that is easily accessible like this, I believe it would be convenient to practice." (Interviewee G)

The advantage of the checklist mentioned by the interviewees is that it enables them to recognize the goals of sustainable development and clarify the design approach according to the concept of the brand. Moreover, the checklist is a tool for effectively learning the design approach to sustainability.

As suggestions for the checklist as a practical tool, constant updates, quantification for objective verification, and more in-depth details were mentioned.

"It seems that new ways to express design that pursue sustainability are emerging as time passes. New methods are proposed yearly for ease of recycling and economy, such as using single-component materials, design, and manufacturing that are easy to repair, reward policy, and lightweight to reduce carbon emissions. Therefore, new methods must be updated over time." (Interviewee A)

"When it comes to dyeing, the abuse of water becomes a problem. I have encountered a dry dyeing technique that saves approximately 90% of water use, but it is not on the checklist. It would be good if new methods are constantly updated." (Interviewee F)

Brand A participating in the interview presented numerical values for objective verification.

"Among famous overseas sustainable brands, there are brands that numerically represent sustainability. There is an objective feeling that numbers give. It shows the depth of our participation in sustainability together."

"The checklist is easy to understand and accessible, but I wish it were detailed. The consideration of sustainable design expressions is controversial. For example, in the case of plant leather, natural materials are raw materials, but in some cases, the surface is plasticized to resemble leather during processing. It is said to be an effort toward sustainable development, but I think it may be risky." (Interviewee D)

Suppose the constant update of design expression methods and numerical values for objective verification are supplemented. In that case, the checklist can be a practical method for designers to innovate or change sustainably. Furthermore, it can provide designers with in-depth sustainable knowledge if additional data on items that require discussion are provided.

Discussion

This study identified a sustainable design practice method to satisfy customer sensibility and individual taste that designers need in the early stage of the SFD process. The SFB design approach was categorized through a literature review. Through the SFB case study, specific design expression methods for each category of the SFB design approach considering customer sensibility and personal taste were derived. The contents derived from this process were made into a checklist, and the design approach of Korean SFBs was confirmed through an interview.

It has been about 10 years since global brands in the fashion industry started to develop sustainability initiatives for a circular economy. As a result of case studies, 149 SFBs appeared in articles ranking the SFBs of the world's top popular fashion magazines. In total, 35 brands emerged in the articles in 2019, 19 brands in 2020, and 56 brands in 2021. Although there was a market contraction due to Corona 19, the number of fashion brands increased significantly in 2021 is considered to be related to increased consumer interest in SFD. Given the weight of the impact of the fashion industry on the environment and the design method of a fashion designer can have an influence of 80% on the environment (Ribeiro et al., 2013; Ahmad et al., 2018), a specific SFD method considering the circular economy of products selected by consumers is required. In the sustainable fashion sector, the environmental impact is divided into the manufacturing phase of textile and apparel production and the transportation, product use, and end-of-life phases. In the end, the environmental impact depends on the lifespan of the product and the behavior of consumers, and it can be said that it is essentially caused by the production process in which the product is manufactured and the stage of use (Benkirane et al., 2022). From this point of view, this study focused on the sustainable design method of fashion products preferred by consumers. In other words, a design approach that meets the sensibility and taste of consumers is also related to product life extension, remanufacturing, and recycling, thereby forming a virtuous cycle structure of a circular economy.

In this study, in order to find a sustainable design method that consumers can like, a case study of specific design methods of SFBs appearing in the world's top fashion magazines with many subscribers was conducted. Here, it was confirmed that various design approaches are used for each category proposed in previous studies as a design method for a sustainable circular economy.

In the "eco-friendly materials" design approach to maintain a sustainable raw material supply, "using certified sustainable materials," "highly traceable and non-toxic material," "dyeing process of green peace-certified," "local or nearby materials," and "using packages of organic materials" was applied in a specific way. "Functional durability design" that can reduce consumption, which is the ultimate goal of achieving a circular economy, was oriented toward slow manufacturing by "the quality and durability," "on-demand production," and "changeable design." "Fashion for reuse and remanufacturing," which aims to realize a sustainable circular economy through a virtuous cycle of resources, is the most well-known SFD approach. "Use recycled materials," "sourcing 100% of synthetic fibers waste," "upcycled waste clothing," "repurposing," and "repair and restoration" emerged as specific methods. A specific method that was impressive in the case study was "recycling of plastic bottles into yarn and fabric." Recycling plastic bottles are being recycled in terms of circular economy theory and practice (Qu et al., 2019). Nevertheless, there are still negative views. In the report "Synthetics Anonymous (Changing Markets Foundation, 2021)" published by the Changing Markets Foundation (2021), downcycling plastic made from recycled plastic bottles, that is, clothes using recycled polyester, will eventually end up in landfill or incineration instead of circulating fashion. However, from the perspective of the circular economy, it is considered necessary to recycle the waste. Alternatives should be provided in the sense that today's consumers' product selection is determined by their sensibility and taste. Emotionally durable design is a design strategy that makes it possible to extend the life of a product by "strengthening the user-product relationship" (Norman, 2007; Chapman, 2009; Cooper, 2016). In particular, emotionally durable design has been proposed as an important principle of circular design by some scholars, but the concrete details of how emotional attachment and trust can be achieved in practice are not sufficiently presented (Haines-Gadd et al., 2018).

In the case analysis of this study, "emotionally durable design" appeared as "collaboration with local artisans," "folklore handcrafted touches," "handwoven material sourcing," "personal design concept," and "brand signature pieces."

In an interview survey of SFBs in Korea, the approach of "emotionally durable design" was applied by only a few brands as a sustainable design method. Some of the participants even understood that this design approach was a sustainable design approach, after checking the checklist for a specific design approach of "emotionally durable design." Compared to other design approaches, "emotionally durable design" is composed of abstract keywords, so it is considered that it is not well recognized according to individual characteristics.

Sustainable fashion technology, which reduces fabric loss, "seamless garment technology," "digital printing to reduce water use," and "combined laser robotics" appeared as SFD-specific approaches relatively few compared to other design approaches. The checklist of this study is meaningful in that it can be a tool for designers to easily reach the SFD approach in design practice. However, it is a limitation of the study that we were unable to include a large number of interviewees by conducting interviews with SFBs supported by the Korean government.

Conclusion

This study aimed to identify a sustainable design practice. Based on an empirical case study with a theoretical background, a checklist was developed as a tool for sustainable fashion design methods. The inventory for the sustainable design approach suggested as a result of the case study is expected to provide an efficient design method by lowering barriers to practitioners who have had difficulty accessing the concept and design method of sustainable design.

In the sustainable design approach, some items need discussion according to the producer's values. Concerns have

been raised about the sustainability of fashion brands as a marketing tool in this regard. Accordingly, designers' acquisition of sustainable knowledge is essential. Furthermore, it improves the emotional durability of fashion products, reflecting customer emotions and personal tastes, thereby increasing the sustainability of fashion products. Therefore, the designer's active role is required. This study is significant in that it presents a checklist, an easy and efficient tool to address designers' inadequate knowledge and lack of awareness of sustainability, and a sustainable design practice method that can satisfy customer emotions and personal tastes and improve environmental performance.

Data availability statement

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

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent from the patients/participants or patients/participants legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

Author contributions

YY contributed to the conception and design of the study. SK performed the interview and wrote sections of the manuscript. Both authors contributed to manuscript revision, read, and approved the submitted version.

Conflict of interest

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

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The influence of social capital on farmers' green control technology adoption behavior

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Relying on social capital to promote farmers' adoption of green control technology is of great significance for the governance of rural environment and the realization of sustainable agricultural development. Based on the survey data of 754 farmers in Shandong Province, this paper uses the Probit model and the instrumental variable method to empirically analyze the impact of social capital on farmers' green control technology adoption behavior. The results show that: social capital has a promoting influence on farmers' green control technology adoption behavior; the influence of the three dimensions of social capital on farmers' green control technology adoption behavior is in turn social norms, social networks, and social trust; social networks play an enhanced moderating role in the process of social trust and social norms promoting farmers' green control technology adoption behavior; education level, the number of family labor force and annual family income level have a significant positive impact on farmers' green control technology adoption behavior, while age has a significant negative impact. Therefore, the government should make full use of social capital to promote farmers to adopt green control technology.

KEYWORDS

social capital, green control technology, Probit model, endogenous, instrumental variable method

Introduction

For a long time, the high yield and income of Chinese agriculture have been dependent on the application of a good number of chemical inputs. The long-term excessive and inefficient application of chemical inputs pose a huge threat to the quality of agricultural products, rural ecological environment, and human life and health (Wang et al., 2022). In order to solve the negative externalities of chemical inputs application, the Chinese government has actively promoted green control technology (GCT) since 2006. GCT is an environmentally friendly technology widely used in European and American countries, and it is the sinicization of the concept of Integrated Pest Management (IPM) (Gao et al., 2017). GCT emphasizes the comprehensive utilization

of ecological regulation, biological control, physical, and chemical inducement, and scientific drug use or their combination to effectively control pests and diseases, ensure ecological environment safety, promote agricultural cost savings and increase income, and minimize farmers' dependence on chemical inputs (Yu et al., 2020; Niu et al., 2022). By the end of 2019, the coverage rate of GCT in China was only 37% (Ministry of Justice of the People's Republic of China, 2020), and the application level was not high. How to effectively implement the promotion and application of GCT has become a key issue that needs to be solved urgently in the process of ensuring the quality of agricultural products and promoting the sustainable development of agriculture in China.

Many studies believe that farmers, as direct users and stakeholders of GCT, generally lack enthusiasm for adopting GCT, which makes it difficult to effectively break through the scale of promotion (Lou et al., 2021; Wu and Zhou, 2021). What factors prevent Chinese farmers from adopting GCT? From the perspective of the market, farmers are "rational economic people," and the economic incentive mechanism is the main driving force for the promotion of agricultural technology (Griliches, 1957). Farmers' adoption of GCT requires higher economic costs and certain risks. Farmers will adopt GCT only if the net benefit of GCT is greater than the net benefit of traditional chemical inputs (Martey et al., 2020; Yang et al., 2020). But at this stage, China's green agricultural product market is not perfect, not only the market principle of "high quality and high price" for agricultural products is not reflected, but also the "lemon market" effect is caused by information asymmetry. The "invisible hand" cannot form an effective incentive (Nie et al., 2020). From the perspective of technology extension, training and technical support for farmers is an effective method to promote farmers to adopt GCT (Khanal et al., 2020; Liu et al., 2022). However, China's government-led extension model is faced with many problems, such as limited extension resources, low quality of extension personnel, mismatch between extension content and farmers' needs, and the extension effect is not ideal (Gao et al., 2020; Huang et al., 2022). From the perspective of the policy, although the government has issued a number of guiding documents such as "Opinions on Promoting Green Control of Crop Pests and Diseases" and "Key Points of Green Development of Agriculture and Rural Areas," there is a certain gap between the actual effect and policy expectations due to the dispersion and uncertainty of rural environmental problems, as well as the existence of heterogeneity in the historical and cultural foundation of each village and the level of social and economic development (Li et al., 2019; Huang et al., 2021).

According to the theory of new economic sociology, individuals are embedded in the social structure, and their actions are bound to be restricted by sociological "embedded factors" (Granovetter, 1985). Rural China is a "relational" society based on blood, kinship and geography. Farmers' technology adoption behavior is not only influenced by external factors such as policy and market, but also by the social capital embedded in the rural social environment (Gao et al., 2019). Social capital can promote farmers to break through the existing resource constraints and change the boundary between the adoption and not adoption of agricultural technology through mechanisms such as information dissemination, risk sharing, demonstration, and guidance (Castillo et al., 2021). In addition, the positive externalities of GCT can easily lead to collective action getting into trouble. Social capital can combine individual action with collective action, promote cooperation among individuals, reduce uncertainty in the environment of individual behavior choices, and effectively restrain individual "free ride" behavior (Wulandhari et al., 2022). Previous studies have confirmed the role of social capital in farmers' domestic sewage treatment, overgrazing, irrigation technology (Hunecke et al., 2017; Zhang et al., 2020; Ding et al., 2021), but few people have investigated the impact of social capital on farmers' adoption behavior of GCT. Will the society capital influence farmers' GCT adoption behavior? If this kind of influence exists, what is its mechanism and direction? The answers to the above questions are of great practical significance for understanding the internal logic of farmers' GCT adoption behavior, and formulating and perfecting the GCT promotion policy.

Based on the abundant research achievements of previous scholars, this paper tries to make the following explorations: firstly, most of the literatures focus on the influence of individual characteristics such as gender and education level (Rezaei et al., 2019; Steiro et al., 2020), subjective cognitive characteristics such as cognitive closure and environmental cognition (Abadi, 2018; Rezaei et al., 2020), and institutional policy characteristics such as technology promotion models and land ownership on farmers' GCT adoption behavior (Gao et al., 2017; Wang et al., 2018, 2020), but less on the influence of social capital. In fact, besides the characteristics of general agricultural technology, GCT also has typical positive externalities, which can easily lead to "collective action dilemma." The social capital hidden in the peasant group can effectively solve this dilemma through information transmission, demonstration effect, internal supervision and reciprocal cooperation. Therefore, this study examines the influence of social capital on farmers' GCT adoption behavior from different dimensions, which broadens the research perspective. Secondly, the literature does not pay attention to the relationship between different dimensions of social capital. For example, Zhang et al. (2020) verified the influence of social trust, networks and norms on farmers' domestic sewage treatment, but ignored the interaction between them. Based on the comparative analysis of the differences in the influence of social trust, social norms, and social networks on farmers' GCT adoption behavior. This study further examines the moderating role of social networks in the influence of social trust and social norms on farmers' GCT adoption behavior,

which improves the depth of research content. Thirdly, the literature is not aware of the possible endogenous problems. For example, Ogunleye et al. (2021) ignored the endogeneity of social networks when analyzing the impact of social capital networks on farmers' adoption of climate change adaptation strategies. This study eliminates the endogenous influence of social capital and farmers' GCT adoption behavior on the regression results through instrumental variable method, which improves the accuracy of the research results.

The structure of the full text is as follows: Section "Introduction" introduces the implementation background of GCT in China. Section "Theoretical analysis and research hypothesis" introduces the theoretical framework of the influence of social capital on farmers' GCT adoption behavior. Section "Research design" introduces the definition of variables, research methods, and data sources. Section "Estimation results and discussion" introduces empirical analysis and discussion of the results of the impact of social capital on farmers' GCT adoption behavior. Section "Conclusion and policy suggestions" summarizes the main conclusion and policy implications.

Theoretical analysis and research hypothesis

The concept of social capital originated in the field of sociology, which was first put forward and systematically expounded by Bourdieu (1986). He believed that social capital is a network of relationships that helps actors obtain actual or potential resources. Subsequently, Coleman (1988) defined social capital as a personal capital property characterized by social structural resources from a functional perspective. Putnam and Leonardi (1994) promoted social capital from the individual level to the collective level, and believed that social capital is a certain feature of social organizations, including social trust, social networks, and social norms. Since then, the academic research on the definition of social capital has gradually moved closer to social trust, social networks, and social norms. Therefore, the social capital in this paper refers to the mutual trust, relationship network and common values among farmers formed in rural long-term life contacts, which can be summarized into three dimensions: social trust, social networks, and social norms. Its influence on farmers' GCT adoption behavior is as follows:

Social trust and farmers' green control technology adoption behavior

Social trust refers to the subjective probability that a social individual evaluates that other individuals will take a specific action in the future, and this evaluation will have an impact on the social individual's own actions. To a certain extent, social trust determines whether farmers are willing to pay credit or rely on others' suggestions to act, which will constrain or motivate farmers' "free ride" psychology in collective action, and then encourage or inhibit farmers' participation in collective action (Ma et al., 2022). Social trust can be further divided into interpersonal trust and institutional trust. Interpersonal trust, which uses the emotion between people as a bond, often occurs between relatives and friends, and has the characteristics of closeness and distance, which also causes the difference of trust strength. Good interpersonal trust can enhance farmers' mutual identity, increase farmers' willingness to share information resources, promote the flow and transformation of information, and reduce information asymmetry in farmers' adoption of GCT (Granovetter, 1985). Institutional trust often depends on institutional environments such as legal, political and so on. In rural areas, Farmers' institutional trust can be measured by their trust in village cadres (He et al., 2018). A higher level of institutional trust is conducive to enhancing the guarantee role of the government and village cadres, overcoming the farmers' psychology of "uncertainty in adopting GCT," restraining the generation of farmers' opportunistic behavior and avoiding the "prisoner's dilemma" (Cao et al., 2020). Based on this, this paper proposes the hypothesis:

> H_1: Social trust will promote farmers' GCT adoption behavior.

Social networks and farmers' green control technology adoption behavior

Social networks are relatively stable social system formed by the interaction between individual members of society, which emphasizes the interaction and connection between people. According to the view of embeddedness, the individual's behavior decision is not completely independent, but will be influenced by other members in the network (Granovetter, 1985). In China's rural areas, such a social environment with complex local relations, the influence of farmers' social networks on their behavior decisions is more obvious (Gao et al., 2022). Due to the heterogeneity of social networks, social networks can be further divided into strong ties and weak ties (Ostrom, 2010). Strong ties refer to the strong homogeneity of personal social networks and the close relationship between people, which put more emphasis on the strength of social networks. Due to the reciprocal motives among members, strong ties can reduce the cost of obtaining and analyzing information for farmers, and provide opportunities for mutual learning, exchange and help (Zheng and Luo, 2022). Weak ties refer to individuals with strong heterogeneity in their social networks and not close relationship between people, which can better reflect the breadth of social networks. Due to its relatively open

nature, weak ties are more conducive to farmers to obtain more external information across strata, broaden farmers' horizons, reduce cognitive bias, and promote collective action (Granovetter, 1973). Based on this, this paper proposes the hypothesis:

> H_2: Social networks will promote farmers' GCT adoption behavior.

Social norms and farmers' green control technology adoption behavior

Social norms are the rules and principles that members of a group abide by without legal constraints. Individuals usually want to be recognized by the group and try to escape potential social criticism or sanctions from others (Abrahamse and Steg, 2013). Social norms can exert tangible or intangible pressure on members, and promote the behavior of group members to be consistent with the group (Heinicke et al., 2022). Social norms can be further divided into imperative norms and descriptive norms. Imperative norms refer to the behavioral standards that most people approve of and think should be taken or most people oppose and think should not be take. Imperative norms motivate individuals to choose behaviors consistent with the behavior of the majority through social constraints or rewards (Li et al., 2021). Descriptive norms refer to the behavior standards formed by the behaviors that most people have taken or are taking in specific situations. When individuals lack sufficient information to make judgments, they will refer to the behavior of other social members as the basis for their own behavior, and show behaviors similar to other social members, showing an obvious "herd effect" (Asch, 1956). Based on this, this paper proposes the hypothesis:

> H_3: Social norms will promote farmers' GCT adoption behavior.

The moderating role of social networks

Social trust is the product of universal contact and communication between individuals, which is undoubtedly embedded in social networks and deeply restricted and influenced by social networks (Huang et al., 2021). There are two mechanisms by which social networks affect social trust: the first is the "resource" mechanism based on the "social resource theory." The degree of individual trust in others depends on the ability to bear losses. Farmers usually obtain social resources from social networks. Farmers with more social networks are more tolerant of others' untrustworthiness, while farmers with fewer social network resources are less afraid to risk trusting others (Lin, 2001). The second is the "communication" mechanism based on the "contact theory." Through constant contact, farmers can generalize the cognitive experience gained from interacting objects to others who have no contact but have similar characteristics, thereby changing their attitudes and even giving them trust (Skaalsveen et al., 2020). Based on this, this paper proposes the hypothesis:

> H_4: Social networks play an enhanced moderating role in the process of social trust promoting farmers' GCT adoption behavior.

Social networks are not only resources, but also the power to produce collective action, which is rooted in the norms of social networks (Ushchev and Zenou, 2020). From the logic of individual action, one is economic rationality and the other is social rationality. The pursuit of economic rationality is to obtain resources through transactions and maximize economic benefits. Social rationality hopes to obtain reputation and social recognition through relationships, and realize value through groups and networks, which relies on the social laws of groups (Lin, 2001). Social networks require people to take collective action values as the rational basis, first give up self-interest, and rely on collective interests to act. Farmers often hope to gain reputation and social recognition through groups and networks. Therefore, the larger the social networks, the greater the social norms that reflect the reputation utility. Based on this, this paper proposes the hypothesis:

> H_5: Social networks play an enhanced moderating role in the process of social norms promoting farmers' GCT adoption behavior.

Based on the above theoretical analysis, this paper constructs a theoretical analysis framework, as shown in **Figure 1**.

Research design

Variable assignment

Dependent variable

The dependent variable of this paper is farmers' GCT adoption behavior. GCT includes four technologies: ecological regulation, biological control, physical and chemical control, and scientific drug use. Considering that the current penetration rate of GCT in China is not high, referring to related studies (Gao et al., 2019; Yu et al., 2021), we use the binary variable method to measure farmers' adoption behavior. When farmers adopt any one or more of these techniques, the value is 1, otherwise the value is 0.

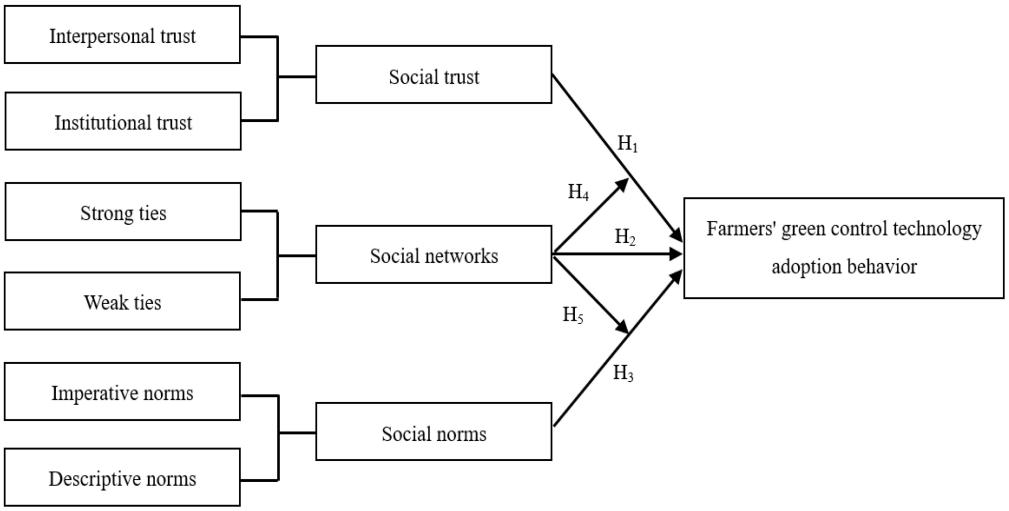

FIGURE 1
Theoretical analysis framework.

Core independent variables

The core independent variables of this paper are three dimensions of social capital, namely, social trust, social networks, and social norms. Referring to relevant literature, this paper measures social trust, social networks, and social norms as follows: ① Social trust. The trust degree of farmers to their relatives and friends is used to represent interpersonal trust (Joffre et al., 2020), and the trust degree of village cadres is used to represent institutional trust (He et al., 2018), and the average of them is taken as the final value of this index. ② Social networks. The communication frequency with villagers in other villages is used to represent the weak ties, and the communication frequency with villagers in this village is used to represent the strong ties (Kreft et al., 2021), and the average of them is taken as the final value of this index. ③ Social norms. The number of people in the village where farmers believe that GCT should be adopted is used to represent the imperative norm, and the number of people who adopt GCT in the village where the farmers are located is used to represent the descriptive norm (Li et al., 2022), and the average of them is taken as the final value of this index. All variables are classified according to Likert scale.

Control variables

According to the existing research results of influencing factors of farmers' GCT adoption behavior, gender, age, education level, and health status are selected from the individual characteristics (Khataza et al., 2018; Rezaei et al., 2019; López-Felices et al., 2022), and the number of family labor force, annual family income, planting scale, and distance from village committee (Cheng et al., 2019; Zhou et al., 2019) are selected from the family characteristics, with a total of eight variables as control variables.

Instrumental variable

Since social networks are often characterized by "self-selection," the adoption of GCT and social networks may show a reverse causal relationship, that is, in the process of understanding, learning, adopting, and exchanging GCT, farmers may enhance their social networks observations due to frequent interactions with their relatives and friends (Marvuglia et al., 2022). Therefore, referring to relevant research (Wei et al., 2018), we select "the number of farmers' New Year's greetings during the Spring Festival" as an instrumental variable of the social networks to deal with the above-mentioned endogeneity problem. The reasons are as follows: Firstly, New Year's greetings during the Spring Festival are one of the most important cultural traditions and customs in Chinese society, especially in rural areas. It has a positive impact on the establishment, maintenance and expansion of farmers' social networks, and has a positive effect on the resources they use from social networks. Secondly, paying New Year's greetings to relatives and friends during the Spring Festival is mainly restricted by the traditional culture and customs on people's behavior, but not directly related to farmers' GCT adoption behavior. Therefore, the number of New Year greetings meets the requirements of tool variables.

The names and definitions of variables are shown in **Table 1**.

Model construction

"Green control technology adoption behavior" is a binary choice problem, so the binary Probit model is constructed, and the expression is as follows:

$$y_i = \alpha_i + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \gamma X + \varepsilon_i \quad (1)$$

TABLE 1 Variables definition and descriptive statistics.

Type	Name	Definition and measure	Mean	Standard deviation
GCT adoption behavior	Whether to adopt	Not adopted = 0; adopted = 1	0.43	0.37
Social trust	Interpersonal trust	Trust in relatives and friends: very distrust = 1; distrust = 2; general = 3; trust = 4; very trust = 5	3.38	0.75
	Institutional trust	Trust in village cadres: very distrust = 1; distrust = 2; general = 3; trust = 4; very trust = 5		
Social networks	Strong ties	Communication frequency with villagers in this village: No contact = 1; less contact = 2; general = 3; more contacts = 4; frequent contacts = 5	3.47	0.82
	Weak ties	Communication frequency with villagers in other village: No contact = 1; less contact = 2; general = 3; more contacts = 4; frequent contacts = 5		
Social norms	Imperative norms	Number of people in the village who think that GCT should be adopted: None = 1; less = 2; general = 3; more = 4; all = 5	3.21	0.98
	Descriptive norms	Number of people adopting GCT in the village: None = 1; less = 2; general = 3; more = 4; all = 5		
Individual characteristics	Gender	Female = 0; male = 1	0.78	0.36
	Age	Respondent's actual age/years	53.42	12.86
	Education level	Primary school and below = 1; junior high school = 2; senior high school = 3; junior college = 4; university and above = 5	2.46	0.98
	Health status	Very poor = 1, poor = 2, fair = 3, good = 4, very good = 5	4.14	0.90
Family characteristics	Number of labor force	Actual labor force/person	4.33	1.42
	Annual income	Annual income in 2021/million RMB	7.61	4.67
	Planting scale	Planting area /mu	8.45	162.44
	Distance from village committee	Distance from residence to village committee /km	0.96	0.75
Instrumental variable	Social networks Instrumental variable	Number of New Year's greetings in 2021	5.22	2.34

In Eq. 1, y_i is whether farmers have adopted GCT, the value of which has been adopted is "1," and the value of not adopted is "0." X_1 is social trust, X_2 is social networks, X_3 is social norms, X is control variables. β and γ are the coefficients to be estimated. Among them β_1, β_2, β_3, and γ are used to judge the influence of social trust, social networks, social norms, and control variables on farmers' GCT adoption behavior. ε_i is a random error term.

In order to further verify the moderating effect of social network in farmers' GCT behavior, this paper uses the interaction term moderating effect analysis model for regression. The specific form of the model is as follows:

$$y_i = \alpha_i + \beta_1^{'} X_1 + \beta_2^{'} X_2 + \beta_3^{'} X_3 + \beta_4 (X_1 \times X_2) + \beta_5 (X_1 \times X_3) + \gamma^{'} X + \varepsilon_i^{'} \quad (2)$$

$X_1 \times X_2$ is the interaction item between social trust and social networks, and $X_1 \times X_3$ is the interaction item between social norms and social networks.β_4 and β_5 are used to judge the moderating effect of social networks on social trust and social norms. And the Eq. 2 there may be endogenous problems between social networks and farmers' GCT adoption behavior. Therefore, the instrumental variable method (IV-Probit) is further used to eliminate the estimation bias caused by endogenous problems.

Data sources

The data used in this study comes from our team's questionnaire survey of vegetable farmers in Shandong Province. The reasons for choosing Shandong Province are: Firstly, Shandong Province is the main vegetable producing area in China, and its vegetable planting area and output have ranked first in the country for many years. Secondly, Shandong Province is one of the provinces with frequent pests and diseases, and the situation of vegetable pest control is severe. Thirdly, Shandong Province is a key area for promoting GCT in China, and the number of demonstration counties ranks first in the country (Ministry of Agriculture and Rural Affairs of China, 2021). Fourth, Shandong is the birthplace of Chinese Confucianism, with a strong "relationship culture" and a more obvious role of social capital. Therefore, it is of typical significance to select Shandong Province as the case area.

The survey was conducted twice, a preliminary survey in November 2021 and a formal survey in February–March 2022. In the first survey, 20 farmers were randomly selected for family interviews in Shandong Province, and the farmers' adoption of GCT was initially understood, and the questionnaire was revised and improved. In the second survey, stratified sampling and random sampling were adopted. First, two counties were selected in each city, then two towns were randomly selected from each county, and then one or two sample villages were randomly selected in each sample town. Finally, 10 farmers were randomly selected in each village for investigation (Figure 2). Face-to-face interviews were used to gain an in-depth understanding of the survey of individual farmers and their families, social capital and adoption of GCT. A total of 800 questionnaires were distributed in this survey, and 754 valid questionnaires were collected, with an effective rate of 94.3%, excluding invalid questionnaires such as unreturned questionnaires, missed answers or stopped answers in the middle of the survey.

According to the situation of farmers' adoption of GCT (Figure 3), among 754 farmers, 265, 163, 67, and 221, respectively, adopted ecological regulation, biological control, physical, and chemical inducement and scientific drug use, accounting for 35.15, 21.62, 8.89, and 29.31% of the total samples. It shows that farmers adopt different proportions of different sub-technologies in GCT, with the highest proportion of ecological regulation and the lowest proportion of physical and chemical inducement. From the perspective of technology combination, there are 136 farmers who have not adopted any sub-technology, accounting for 18.04%; 278 farmers have

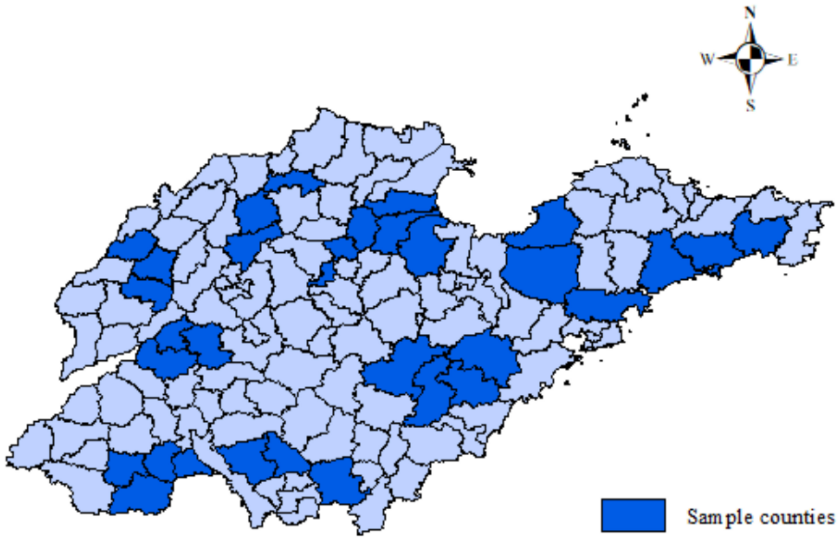

FIGURE 2
Study area.

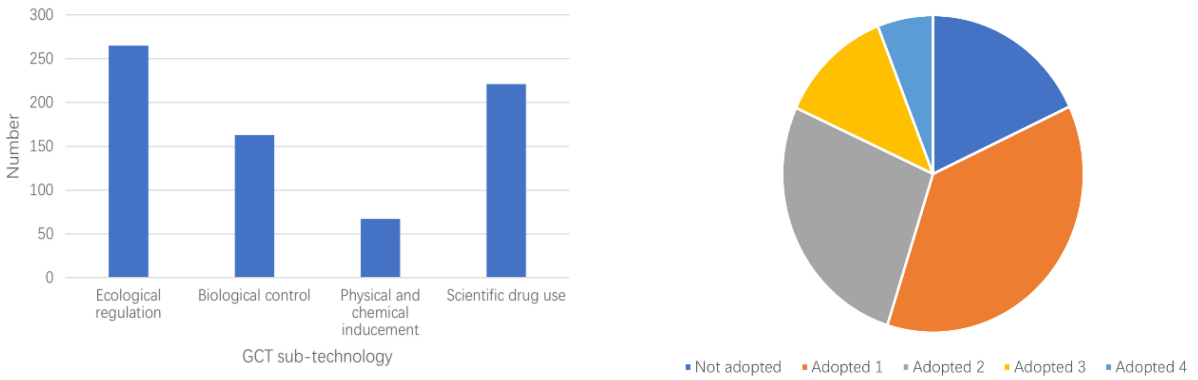

FIGURE 3
Adoption of farmers' green control technology (GCT) sub-technology.

adopted 1 sub-technology, accounting for 36.87%; 203 farmers have adopted 2 sub-technologies, accounting for 26.92%; 92 households adopt 3 sub-technologies, accounting for 12.20%; 45 households adopt all 4 sub-technologies, accounting for 5.97%. It shows that the adoption of GCT by farmers is a gradual process, and different farmers have different degrees of adoption of GCT.

Table 2 shows the basic characteristics of the sample farmers. It is not difficult to find that the sample farmers are mainly male, accounting for 78.11%. They are older, with 38.20% of farmers in the 46–55 age group. The education level is relatively low, and 39.39% of the farmers' education level is junior high school. 67.11% of households have a labor force of 4–6 people. 42.44% of farmers have a planting area of 6–10 mu. The total household income is 51.32% with the highest proportion of farmers with 50,000–100,000.

Estimation results and discussion

Model inspection

Reliability, validity, and correlation test

In this study, the reliability and validity of the data were tested. It can be seen from Table 3 that Cronbach's α coefficient values of social trust, social networks, and social norms are all greater than the reference standard of 0.7, indicating that the internal consistency of the research data is good. The CR value of each variable is greater than 0.9, which meets the inspection standard. AVE values of all variables are greater than 0.7, which indicates that the aggregation validity of this research scale is good. The square root of each variable AVE is larger than its correlation coefficient with other variables (Table 4), indicating that the research data has good discrimination validity. It can be seen from Table 4 that the correlation coefficients among social trust, social networks, social norms, and GCT adoption behavior are all significantly correlated at the level of 1%.

TABLE 3 Reliability and validity test results.

Variable	Cronbach's α	KMO	CR	AVE
Social trust	0.934	0.892	0.928	0.812
Social networks	0.956	0.904	0.953	0.805
Social norms	0.947	0.878	0.950	0.827

Multiple collinearity test

This paper uses stata 13.0 software for regression analysis. Firstly, considering the multicollinearity problem between variables, the Variance Inflation Factor method (VIF) was used to test the independent variables. The test results show that the VIF values between all independent variables were less than 10, which satisfies the principle of independence, and there is no significant collinearity. Secondly, the social trust, social networks and social norms are separately incorporated into the model, and the model 1–3 is obtained. Finally, the social trust, social networks, and social norms are incorporated into the model, and the model 4 is obtained. From the significance of each model (Table 5), all passed the 1% significance test, indicating that the model has a good degree of fit. Compared with model 1–3, the Pseudo R^2 of model 4 increased to 0.227, which has stronger explanatory power. It shows that model 1–3 does not include the three dimensions of social capital at the same time, resulting in the omission of variables, which will overestimate the influence of the three dimensions of social capital on farmers' GCT adoption behavior.

TABLE 2 Basic information of sample farmers.

Variable	Category	Frequency/person	Proportion/%	Variable	Category	Frequency/person	Proportion/%
Gender	Male	589	78.11	Number of labor force	≤3	211	27.98
	Female	165	21.89		4–6	506	67.11
Age	≤45	144	19.10		≥6	37	4.91
	46–55	288	38.20	Annual income//million RMB	≤5	258	34.22
	56–65	181	24.01		5–10	387	51.32
	≥66	141	18.69		≥10	109	14.46
Education level	Primary school	127	16.84	Planting scale /mu	≤5	231	30.64
	Junior high school	297	39.39		6–10	320	42.44
	Senior high school	165	21.88		11–20	134	17.77
	Junior college	111	14.72		21–50	54	7.17
	University and above	54	7.17		≥51	15	1.98

TABLE 4 Correlation coefficient matrix.

	1	2	3	4	5	6	7	8	9	10	11	12
1	–											
2	0.022	–										
3	0.005	−0.258	–									
4	−0.013	−0.443*	0.064	–								
5	0.052	−0.073	−0.012	0.069	–							
6	−0.027	0.092	0.358**	0.282	0.201	–						
7	0.049	−0.054	0.170	0.045	0.165	0.177*	–					
8	0.032	0.014	0.221	0.005	0.009	0.022	0.003	–				
9	0.105	−0.089*	0.328**	0.099	0.086	0.072	0.030	0.231*	(0.905)			
10	0.288	−0.050*	0.140	0.212	0.060	0.113	0.042	0.159	0.343**	(0.892)		
11	0.195	−0.105*	0.424**	0.162	0.108	0.101	0.018	0.072	0.321	0.357***	(0.911)	
12	0.174	−0.094*	0.293**	0.183	0.096**	0.166**	0.028	0.102	0.371***	0.362***	0.366***	(0.889)

*, **, and *** indicate significant at the 10, 5, and 1% levels, respectively. The value in brackets is the square root of AVE. (1) Gender; (2) Age; (3) Education level; (4) Health status; (5) Number of labor force; (6) Annual income; (7) Planting scale; (8) Distance from the village committee; (9) Social trust; (10) Social networks; (11) Social norms; (12) GCT adoption behavior.

TABLE 5 Estimated results of the impact of social capital on farmers' green control technology (GCT) adoption behavior (benchmark regression).

Name	Model 1		Model 2		Model 3		Model 4	
	Marginal effect	Standard error	Marginal effect	Standard error	Marginal effect	Standard error	Marginal effect	Standard error
Social trust	0.047***	0.026	–	–	–	–	0.033**	0.031
Social networks	–	–	0.055***	0.014	–	–	0.038***	0.021
Social norms	–	–	–	–	0.063***	0.037	0.041***	0.026
Gender	0.096	0.026	0.103	0.027	0.111	0.026	0.105	0.025
Age	−0.003**	0.002	−0.001**	0.002	−0.002*	0.002	−0.003*	0.002
Educational level	0.029***	0.058	0.031***	0.060	0.035***	0.065	0.032***	0.062
Health status	0.002	0.005	0.001	0.005	0.003	0.005	0.004	0.005
Number of labor force	0.062***	0.025	0.062***	0.026	0.067***	0.025	0.061***	0.025
Annual income	0.022**	0.004	0.023**	0.005	0.018**	0.005	0.018**	0.004
Planting scale	0.014	0.007	0.016	0.005	0.016	0.006	0.017	0.007
Distance from village committee	−0.002	0.003	−0.002	0.003	−0.002	0.003	−0.002	0.003
Chi-square statistics	173.470***		161.070***		185.215***		197.857***	
Pseudo R^2	0.206		0.193		0.215		0.227	

Probit estimation results report marginal effect, and the standard error is calculated by delta method; *, **, and *** indicate significant at the 10, 5, and 1% levels, respectively.

Endogenous test

Considering that there may be endogeneity between farmers' GCT adoption behavior and social networks, this paper uses IV-Probit model to test endogeneity. Firstly, the endogenous variables are used as the explained variables and the instrumental variables are used as the explanatory variables for regression to obtain the fitting value of the endogenous variables. Then, the fitting value is used as an explanatory variable to introduce the Eq. 1 for regression. In the first stage of model regression, Wald's endogeneity test results show that the hypothesis that there is no endogeneity is rejected at 1% level. The F value of the first stage is 39.47, which exceeds the minimum requirement of $F = 10$ for IV validity, indicating that there is no weak tool variable problem. The IV-Probit two-stage estimation results (Table 6) show that both models 2* and 4* including social networks variables have endogeneity problems (the assumption that all explanatory variables are exogenous cannot be satisfied), and the instrumental variable method is appropriate. Among them, the marginal effect values of the three dimensions of social capital in model 4* are all higher than those in model 4, indicating that if the endogeneity problem is not dealt with, its impact on farmers' GCT adoption behavior will be underestimated. In addition, because Model 2* only includes social networks variable, its marginal effect value is larger than Model 4*, that is, the impact of social networks on farmers' GCT adoption behavior is overestimated. Therefore, this paper takes the estimation result of Model 4* as the main explanation result.

TABLE 6 Estimated results of the impact of social capital on farmers' green control technology (GCT) adoption behavior (instrumental variable method).

Name	Model 2*		Model 4*	
	Marginal effect	Standard error	Marginal effect	Standard error
Social trust	—	-	0.036**	0.044
Social networks	0.055***	0.025	0.043**	0.054
Social norms	—	-	0.050**	0.062
Gender	0.427	0.117	0.429	0.124
Age	−0.014**	0.006	−0.015**	0.006
Educational level	0.028* ∗ *	0.063	0.036***	0.067
Health status	0.007	0.016	0.002	0.018
Number of labor force	0.125***	0.053	0.132***	0.056
Annual income	0.053**	0.014	0.059**	0.011
Planting scale	0.026	0.009	0.038	0.008
Distance from village committee	−0.008	0.010	−0.007	0.011
Wald test value	0.016		0.004	
Prob > χ^2	0.000		0.000	

Probit estimation results report marginal effect, and the standard error is calculated by delta method; *, **, and *** indicate significant at the 10, 5, and 1% levels, respectively.

Benchmark regression result analysis

The estimation results of Model 4* show that social trust, social networks and social norms all promote farmers' GCT adoption behavior, and the significance level is 5%, which verifies the hypotheses H_1–H_3. A good level of social trust can make the communication between farmers smoother, reduce the information asymmetry in farmers' adoption of GCT, improve farmers' enthusiasm for cooperation with others and their trust in policy implementation, thus encouraging farmers to adopt GCT. Social networks can broaden the channels for farmers to obtain GCT information, increase the possibility of mutual learning, reduce the cost of farmers' technical information search and technical learning, and promote them to adopt GCT. Social norms often reflect the opinions of most farmers in the village. When most farmers in the village adopt GCT, they will consciously adopt GCT under the dual influence of herd psychology and curiosity psychology.

From the marginal effect results, the probability of farmers adopting GCT will increase by 5.0% for each additional unit of social norms, 4.3% for each additional unit of social networks, and 3.6% for each additional unit of social trust. It shows that social norms play the strongest role, followed by social networks, while social trust plays the weakest role. The possible reason is that social norms are the deepest social embedment, deeply rooted in individual consciousness, guiding farmers' behavior imperceptibly, and having a deeper and wider influence on farmers' behavior. Social trust and social networks can only enhance farmers' understanding of GCT to a certain extent, but they do not play a leading role in the adoption of GCT, so their influence is relatively small.

Influence of control variables

Model 4* shows that age passed the 5% significant level test. The older the farmers are, the lower their ability to understand and accept new technology, and their motivation and passion for learning are also lower than those of young farmers. Therefore, the lower the possibility of adopting GCT. Education passed the 1% significant level test. Farmers with a higher education level have a certain knowledge reserve, so it is easier to understand the mechanism of GCT, and it is easier to solve problems arising from the implementation of GCT, and the higher the probability of adopting GCT. The number of household labor force passed the 1% significant level test. The implementation of GCT requires household to invest a certain amount of labor force. The greater the number of household labor force, the more energy and ability to learn and implement GCT. The annual household income passed the 5% significant level test. Farmers with higher annual income are more resistant to business risks and have more confidence in adopting GCT.

Moderating effect analysis

The interaction terms of social networks and social trust, social networks, and social norms are introduced into Eq. 2,

TABLE 7 Estimated results of the impact of social capital interaction terms on farmers' green control technology (GCT) adoption behavior (instrumental variable method).

Name	Model 5		Model 6	
	Marginal effect	Standard error	Marginal effect	Standard error
Social networks × social trust	0.021**	0.008	—	—
Social networks × social norms	—	—	0.029**	0.015
Social trust	0.059**	0.037	0.045**	0.033
Social networks	0.071*	0.025	0.057**	0.040
Social norms	0.080*	0.028	0.063*	0.036
Control variable	Controlled		Controlled	
Wald test value	0.025		0.011	
Prob > χ^2	0.000		0.000	

Probit estimation results report marginal effect, and the standard error is calculated by delta method; * and ** indicate significant at the 10 and 5% levels, respectively.

TABLE 8 Estimated results of the impact of social capital on farmers' green control technology (GCT) adoption behavior (group regression model).

Name	Model 7		Model 8	
	Low social networks farmers		High social networks farmers	
	Marginal effect	Standard error	Marginal effect	Standard error
Social trust	0.039***	0.012	0.068***	0.021
Social norms	0.061***	0.018	0.075***	0.024
Control variable	Controlled		Controlled	
Pseudo R^2	0.196		0.214	
Chi-square test	75.336***		101.482***	

Probit estimation results report marginal effect, and the standard error is calculated by delta method; *** indicate significant at the 1% levels, respectively.

respectively, for IV-Probit regression, and model 5 and model 6 are obtained (Table 7). Model 5 shows that the interaction between social networks and social trust has a positive impact on farmers' GCT adoption behavior at a significant level of 5%, indicating that social networks play an enhanced moderating role in the impact of social trust on farmers' GCT adoption behavior, and research hypothesis 4 has been verified. The possible explanation is that the distribution of social networks in rural China presents a disparate pattern, and there are frequent interactions and exchanges between relatives and neighbors. Such interactions and exchanges have created a good environment of social trust and enhance the impact of social trust on farmers' GCT adoption behavior. Model 6 shows that the interaction between social networks and social norms has a positive impact on farmers' GCT adoption behavior at a significant level of 5%, indicating that social networks play an enhanced moderating role in the impact of social norms on farmers' GCT adoption behavior, and research hypothesis 5 has been verified. The possible explanation is that the influence of social norms needs to be based on social networks. The more developed farmers' social networks are, the stronger the role of social norms rooted in social networks will be, so as to better play the role of social norms in farmers' GCT adoption behavior.

Robustness test

Considering that the selected model will have an impact on the regression results, this paper further selects the Logit grouping regression model to explore the impact of social capital on farmers' GCT adoption behavior for robustness testing (Table 8). Specifically, according to the average value of farmers' social networks of 3.47, the farmers' social networks score greater than or equal to 3.47 are defined as high social networks farmers, and the farmers' social networks score less than 3.47 are defined as low social networks farmers. Compare the influence of different groups' social trust and social norms on farmers' GCT adoption behavior.

Table 8 shows that the impact of social trust on the adoption of GCT by two groups of farmers is significant at the 1% statistical level, and the marginal effect is positive. However, from the perspective of influence intensity, the positive impact of social trust on farmers' GCT adoption behavior of high social networks group is stronger than that of low social networks group farmers, that is, social networks can indeed enhance the positive impact of social trust on farmers' GCT adoption behavior. The impact of social norms on the adoption of GCT by two groups of farmers is significant at the 1% statistical level, and the marginal effect is positive. However, from the perspective of influence intensity, the positive impact of social norms on farmers' GCT adoption behavior of high social networks group is stronger than that of low social networks group farmers, that is, social networks can indeed enhance the positive impact of social norms on farmers' GCT adoption behavior. The estimation results in Table 8 are basically similar to the above analysis results, indicating that the estimation results in this paper are relatively robust.

Conclusion and policy suggestions

Conclusion

Based on the survey data of 754 farmers in Shandong Province, this paper empirically analyzes the influence of social capital on farmers' GCT adoption behavior. The results show that: firstly, the three dimensions of social capital (social trust, social networks, and social norms) all play a role in promoting farmers' GCT adoption behavior. Among them, social norms play the strongest role, followed by social networks, and social trust is the weakest. Secondly, social networks play an enhanced moderating role in the process of social trust and social norms promoting farmers' GCT adoption behavior. Thirdly, education level, household labor force, and annual income have significant positive effects on farmers' GCT adoption behavior, while age has significant negative effects.

Policy suggestions

Based on the study, this paper puts forward the following suggestions:

1. The government should vigorously cultivate rural non-governmental organizations such as agricultural cooperatives and agricultural associations, and build a good platform for farmers to exchange and learn from each other; use modern information technology to optimize and expand farmers' access to information, and guide farmers to actively participate in exchanges and experience sharing; encourage farmers to make good use of their own social network resources such as neighbors from the same natural village, friends from different natural villages, relevant intermediaries or service organizations, so as to expand their own social networks.
2. The government should make full use of rural radio, television, and Internet to create a social atmosphere of mutual trust and mutual benefit; actively organize rural cultural activities and production mutual assistance activities, and improve the level of trust among farmers and between farmers and village cadres by showing the working ability and people-friendly style of village cadres in the activities and making use of cooperation and exchange.
3. Encourage large farmers and family farms in the village to adopt GCT, highlight the exemplary role of typical characters, and give full play to its demonstration effect; actively guide the villages to form social norms such as village rules, customs, and habits that are coordinated with them, and strengthen farmers' reputation utility and social responsibility awareness, so as to give full play to the internal driving force of reputation mechanism in the process of promoting the adoption of green control technologies, and finally guide them to form a good ecological consciousness.
4. The grass-roots governments, village collectives and villagers' groups should guide farmers to adopt GCT in an orderly manner in batches, starting from young farmers with high education level, large number of family labor force and high annual family income, so as to give play to the leading role of these farmers.

Limitations and future research

The limitation of this study is that the study area is relatively narrow, and the phenology of the crop production and agronomic behavior of the farmers are expected to be similar. China's rural areas are vast and have significant differences, so we can consider expanding the scope of research in the future. At the same time, the research data of this study is limited to 2022, and we can try to establish long-term tracking panel data in the future.

Data availability statement

The original contributions presented in this study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

ZR: writing—original draft. ZF and KZ: reviewing and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

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Psychophysiological restorative potential in cancer patients by virtual reality (VR)-based perception of natural environment

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The positive significance of nature to human' self-reported well-being has been widely confirmed, but less attention has been paid to the study of cancer patients, as well as the role of time on the restorative effects. Therefore, using virtual reality (VR) and the inclusion of patients with esophageal and gastrointestinal cancer as participants, this study conducted indoor experiments to explore patients' psychophysiological recovery through the perception of five different environmental types with three to five interventions per week. There were 63 participants selected from the People's Hospital in Shaanxi Province. Depending on their psychophysiological state, they would participate in three to five interventions in a week to compare the number of interventions needed to achieve maximum restoration. The five environmental types utilized varied in land cover, vegetation structure, and landscape characteristics, and were identified as blue space (BS), open green space (OGS), semi-open green space (SOS), closed green space (CGS), and gray space (GrS). Before and after viewing landscapes, the changes of psychophysiological indicators were measured to explore the influence of different environmental types on participants. The results showed that the participants preferred and received the highest perceived restorative potentials in BS and lastly, GrS. The green and blue spaces measurably increased positive emotions and perceived restoration while a decreasing negative emotions and the heart rate (HR) compared with the GrS. Participants had the highest level of relaxation while their eyes were closed in the EEG baseline stage. Moreover, participants received the most relaxation when they contacted with nature three times a week, which indicated that excessive natural participation may not be conducive to the sustained development of cancer patients' psychophysiological health. Instead of field appreciation, VR could be utilized to increase the access of cancer patients to nature and then be used as an approach to landscape interaction.

KEYWORDS

esophageal or gastrointestinal carcinoma, EEG, virtual reality, human well-being, interdisciplinary planning

Introduction

The preferences for and positive benefits of natural spaces for the health and well-being of human beings have been widely demonstrated in comparison to urban built spaces (Hartig et al., 2014; de la Barrera et al., 2016; Stigsdotter et al., 2017a). Green and blue spaces, as common forms of natural space and valuable natural resources in cities (Wang et al., 2019; Valente et al., 2020), can bring significant restorative qualities within an environment for their varieties of vegetation and balance of refuge and open scenery (Stigsdotter et al., 2017b). These natural spaces can also function to protect people from illness (Van den Berg et al., 2010). However, considering their attributes vary in type, size, color, and vegetation composition (Huang et al., 2020), it is an important task for landscape architects to identify to which extent different natural spaces can contribute to well-being (Huang et al., 2020), so as to design effective spaces to benefit human health (Olmsted, 1865).

Vegetation structure is the physiognomic character of spatial configuration in green spaces, which can be used as an important quantitative indicator in green space design. The dominant frameworks in nature research have pointed to the importance of spaciousness in nature which has been related to mental restoration (Ulrich, 1993; Kaplan, 1995). Houwelingen-Snippe et al. (2020) also showed that spacious scenes can elicit significantly higher human emotion and social aspiration. However, there is a lack of uniform quantitative classification criteria for the study of spatial configuration characteristics of restorative environments, resulting in uncertainty about what kind of structural components will be more beneficial to human health (Hoyle et al., 2017). Vegetation structure is the most referred to representative configuration in a natural environment setting (Gao et al., 2019b). Therefore, the integration of vegetation structure into the green space classification will be conducive to an effective quantitative design of restorative landscape.

Previous studies on the health benefit of green spaces have considered various respondents with different social characteristics, including park visitors (Qiu et al., 2013), self-reported stressed individuals (Gao et al., 2019a; Huang et al., 2020), college students (Jiang et al., 2019; Gao et al., 2019b), etc. However, as a typical group whose physical and psychological health is generally threatened, few studies have taken the significance of nature intervention on patients into account (Trostrup et al., 2019), especially cancer patients with mobility difficulties due to the medical treatments typically performed in hospital settings. Traditional medical treatments, e.g., hospitalization, chemotherapy, and repeatedly invasive procedures, although significantly prolonging the lives of many cancer patients and in some cases effectively curing them, these results could be accompanied with certain harmful side effects to the body and mind for cancer patients (Chirico et al., 2016). Mental health problems of patients diagnosed with physical diseases have posed a great challenge to health care, and studies have also found that most cancer patients are accompanied by mental health problems (Collins et al., 2011). Therefore, the development of medicine must be combined with social psychology in order to achieve both physical and psychological treatment. As a widely recognized means of psychological recovery (Nilsson et al., 2011), the natural environment intervention seems to be a fairly promising treatment with less adverse reactions. Therefore, an "add-on" treatment for cancer patients based on the intervention of nature could significantly contribute to the modern health care system (Thompson Coon et al., 2011). However, although healing landscapes and horticultural therapy have been used in healthcare (Chang and Chien, 2017), there is still a lack of studies on how patients prefer different landscapes and which types of landscapes are more conducive to their physical and mental restoration, which can provide quantitative theoretical basis and practical methods for the construction of cancer patient-oriented restorative environments.

Until now, most traditional social-psychological studies of patients focus on the self-reported psychological indicators (Trostrup et al., 2019). Attention Restoration Theory (ART) and stress reduction theory (SRT) bring great possibilities to the assessment of self-reported health benefits (Ulrich, 1993; Kaplan, 1995). Raanaas et al. (2012) claimed that cardio-pulmonary patients who were more likely to view panoramic outdoor natural environments had higher levels of self-reported health. Rosenberg et al. (2014) found that brief outdoor adventures had significant positive effects on the psychosocial functioning of adult cancer patients. However, the studies of physiological indicators on cancer patients are relatively scarce. Trostrup et al. (2019) who systematically reviewed the significance of nature on the psychological health of patients, called for further attention to the importance of physical health and the relationship of the two. Studies have shown that people detect visual and auditory signals through the external environment, which then cause physiological response such as autonomic nervous system and measurable changes in electroencephalography (EEG; Li et al., 2021). Many physiological indicators, such as the heart rate (HR; Yu et al., 2020), blood pressure (Lee et al., 2009), and EEG results (Chang et al., 2008; Aspinall et al., 2015; Gao et al., 2019b) have been commonly used in nature and human health studies. Therefore, exploring environmental restoration through physiological measurements has been gradually proven to be reliable.

It is worth noting that previous studies have declared the important effects of contact with the natural landscape for human beings under different time periods of intervention (Lyu et al., 2019), but there is a lack of relevant research with cancer patients, especially for long-term studies with serial nature interventions. Kaplan and Kaplan (1989) mentioned that, with the increase of time, the ability of human beings to inhibit distraction weakens. Therefore, the difference in restoration levels under varying degrees of nature intervention intensity should be taken into consideration as well.

In addition, virtual reality (VR) can be an effective technology utilized in rehabilitation (Shin and Kim, 2015) due to its provision of relaxation by introducing various scenarios (White et al., 2018), and it thus plays a significant role in the physiological and psychological indicator measurements in the process of cancer

treatment. It is non-invasive (Schneider et al., 2011) and provides the respondents with continuous natural experiences (White et al., 2018), which has great application prospects for patients with mobility difficulties. Oyama et al. (1999) suggested that, during the course of chemotherapy, the appreciation of the natural landscape could reduce the negative mood, pain, and anxiety of the patients. However, studies based on VR intervention have less focused on these health benefits of natural exposure, and the relevant outcomes are needed to be scientifically measured (White et al., 2018). In this study, VR was thus introduced to provide a case for the psychophysiological health studies of patients with esophageal and/or gastrointestinal cancer. Considering the lack of psychophysiological recovery studies under different intervention periods for cancer patients, the following three main research questions were developed:

1. What is the most preferred type of environment of cancer patients based on a comparative analysis of the intervention group and the control group?
2. What are the differences in psychological and physiological restoration of cancer patients in the two groups among different types of environment?
3. What is the degree of psychophysiological restoration within cancer patients under multiple interventions in a week?

Materials and methods

Stimulus material

VR technology was used to provide photo-realistic scenes of various landscapes, and panoramic photos were therefore collected as visual stimulus materials. Considering that the participants viewed the panoramic photos indoors instead of participating in on-site investigation, it was critical that the photos be able to represent the typical landscapes and a sense of reality, i.e., authenticity.

To achieve the authenticity, the shooting venues selected as the randomized controlled stimulus materials were the city parks and the hospital respectively, places of which the cancer patients were familiar with and often visit. The panoramic photos were captured for the intervention group in the typical Chinese urban recreational forest parks which were the most welcomed by tourists with beautiful scenery on sunny days with no wind by an Insta 360 Pro-I panoramic camera with 7680*3840 (8 K) pixels in June 2018. Aerial planes were used to determine the canopy cover of the green spaces. The panoramic photos of the hospital indoor environment were also photographed for the control group. The shooting heights of the photos were adjusted to 1.6 m according to the average height of the human eyes in order to maintain authenticity (Jo and Jeon, 2020). There were 140 photos taken in total in the two groups. Nine expert landscape architects, ecologists, and silviculturists were invited to classify and select park photos through a visual and bio-physical characterization of the landscape. First, the photos were divided according to the land cover type into green space (GS) and blue space (BS). Then, the GS was subdivided into open green space (OGS), semi-open green space (SOS), and closed green space (CGS) based on the actual measurements of the canopy cover ratios of trees and shrubs (Figure 1). Next, the most representative photos of BS, OGS, SOS, and CGS were determined by the size, location, species composition, setting configuration, and management regime. Two tumor-related attending doctors and three head nurses were also invited to select the most representative photos of the indoor hospital environment as gray space (GrS). This selection process resulted in five typical types of environment (Figure 1). For each type of environment, five photos were included, and a total of 25 photos were selected, which were displayed in the VR equipment (Pico Goblin VR all-in-one, 2,560*1440 pixels resolution).

Participants

After considering the increasing morbidity in the world and the high mortality rate in China (Anderson et al., 2019; Zhao and Lim, 2020), esophageal and gastrointestinal cancer patients were finally selected as the participants, as they fit the criteria and were willing to participate. The patients with esophageal or gastrointestinal cancer who met the inclusion–exclusion criteria (Table 1) were volunteered for the experiment by the People's Hospital in Shaanxi Province, China. The inclusion–exclusion criteria were created by the tumor-related attending doctors, head nurses, and landscape architects. In total, 70 patients participated in the experiment based on the inclusion–exclusion criteria. Participants were randomly (single-blind) assigned into two groups, the intervention group and the control group. The intervention group was exposed to virtual green and blue spaces, and the control group was exposed to virtual gray space. As a result, 34 participants were in the intervention group and 36 in the control group. Seven respondents (2 in the intervention group and 5 in the control group) were excluded due to incomplete experimental data caused by discomfort halfway through the experiment. Therefore, 63 patients participated, including 32 participants in the intervention group (mean age = 61.31 ± 15.10, 23 males, 9 females) and 31 participants in the control group (mean age = 59.48 ± 12.06, 20 males, 11 females). For participants in the intervention group, their monthly income averaged less than 5,000 RMB (approximately equal to $712.5). Most of them had basic education (less than a senior high school education) and lived in a rural environment. The participants of the control group had similar social demographic information as those of the intervention group. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of College of Landscape Architecture and Arts, Northwest A & F University.

· **Open green space (OGS)**: The canopy cover of trees and shrubs is less than 30% within the green space.

· **Semi-open green space (SOS)**: The canopy cover of trees and shrubs is dominant from 30% to 70% within the green space.

· **Closed green space (CGS)**: The canopy cover of trees and shrubs is more than 70% within the green space.

· **Bluespace (BS)**: There is a large surface area of water, surrounded by plants.

· **Grey space (GrS)**: Hospital building environment.

FIGURE 1
The representative panoramic photographs and description of the five typical types of environment identified by experts according to land cover, canopy cover ratios, size, location, species composition, setting configuration, and management regime. The intervention group viewed various green and blue spaces while the control group viewed the gray space.

Measurement

The study conducted measurements of participants including preference, psychological, and physiological aspects to indicate the level of psychophysiological restoration. Psychological measurements included the Self-Rating Depression Scale (SDS), Perceived Restorativeness Scale (PRS), and the Positive and Negative Affect Scale (PANAS), while physiological measurements included HR, blood pressure (BP), electroencephalogram (EEG), and neutrophil-to-lymphocyte ratio (NLR). Many of these indicators were selected with the guidance of tumor-related attending doctors and the head nurses.

Preference

Participants' perceived preferences for landscape type were obtained by scoring on a seven-point Likert scale when viewing each panoramic photo by VR glasses. It is indicated that higher scores given by the participants signify a greater preference for the respective photo. The participants were encouraged to write down the reasons for the scoring, which was of great importance to further understand their landscape preferences.

Psychological measurement

The level of self-report pressure of the participants was measured by the SDS (Shen et al., 2012), which had been widely used in the self-assessment of clinical depression (Liu et al., 2019). The scale consists of 10 positive items and 10 negative items, and it requires respondents to give scores according to the four occurrence frequencies, ranging from 1 to 4. The total score of the scale can be expressed by the sum of 20 items multiplied by 1.25. The threshold of the scale indicating depression is 53. The higher the scores were, the higher the degree of depression was.

TABLE 1 The inclusion–exclusion criteria that patients with esophageal or gastrointestinal cancer needed to meet in this study.

Inclusion criteria:
a. Over 18 years of age.
b. The patients were diagnosed with esophageal or gastrointestinal cancer by a general surgeon after pathological examination.
c. Have a certain ability to read words, be able to communicate orally and in writing.
d. Voluntary participation in the experiment.
e. No major events such as surgery during the experiment.
Exclusion criteria:
a. The communication is difficult, and the consciousness is not clear.
b. Suffer from other serious physical diseases.
c. Have a history of mental illness; take antipsychotic drugs or have recently stopped taking drugs for less than three months.
d. Other relevant mental and cognitive interventions are in progress.

The perceived restoration of respondents was measured by PRS (Hartig et al., 1997). It contains 16 items according to the attention restoration theory (ART): being away, fascination, coherence, and compatibility. The Likert-7 scale was used with a higher score representing a higher level of restoration potential.

The mood changes of respondents were determined by the PANAS (Watson et al., 1988). The scale consists of 20 items. Ten items indicated negative emotions (PANAS NEG), describing emotions such as nervous, scared, etc. The others indicated positive emotions (PANAS POS), describing emotions such as interested, excited, attentive, etc. The item scores consist of five degrees, from none to extremely. After the stimulation using VR panoramic photos, respondents were asked to fill out this scale to indicate mood changes.

The total Cronbach's α coefficient of the scales is 0.824 for SDS, 0.819 for PRS, and 0.807 for PANAS, respectively (all >0.7), which means that the evaluation projects have high correlations and internal reliabilities are quite reliable.

Physiological measurement and blood sampling

HR and BP were common physiological measurements indicating patients' physical states in environmental psychological studies for their readily available data. HR could be regarded as one of the physiological responses to physiological stimulation and psychological stress (Reeves et al., 2019). BP is divided into diastolic blood pressure (DBP) and systolic blood pressure (SBP), which could be used to indicate the degree of relaxation of the body (Kulkarni et al., 1998).

Electroencephalogram (EEG) had been widely used in the interference study of external stimuli to respondents due to its non-intrusive and rapid collection of brain wave data (Chiang et al., 2017). It can fundamentally measure different aspects of the electrical activity of the brain to some extent. And the reliability of using EEG to measure users' physiological responses in VR interventions has been proved in previous studies (Tarrant et al., 2018; Murphy and Higgins, 2019). The Alpha wave of the EEG is closely related to positive emotion and stress relief. Increased Alpha wave usually indicates relaxation (Klimesch, 1999; Fachner et al., 2013). Considering the previous studies showed that the increase of EEG alpha waves' value can reflect the physiological relaxations experienced when one is exposed to natural features (Gao et al., 2019b), portable brain wave devices (NeuroSky, with the NeuroSky TGAM brain wave chip inside) were used to measure the changes of Alpha waves among participants to indicate their degree of restoration (Cacioppo et al., 2000). Through wireless devices and electrodes connected to the forehead, the brain wave data were transmitted to the computer in real time and displayed in numerical form.

The examinations of the blood samples were conducted to assess the hematological characteristics of the respondents. Neutrophil-to-lymphocyte ratio (NLR), which could reflect systemic inflammatory response and immune status, was selected as one of the physiological indicators (Jiang et al., 2016). Considering that inflammation plays a key role in the occurrence and development of cancer, it is speculated that it can be associated with the development of prognosis in a variety of tumors, including esophageal and gastrointestinal cancers (Murakami et al., 2019). Studies showed that NLR usually increased gradually as pathological stages progress, i.e., the lower its value, the better the survival rate and condition (Shibutani et al., 2013).

Experimental design

The experiments were conducted in the laboratory after communication with the head nurse to ensure no external intervention occurred and consistent physical conditions were maintained throughout experiments. This experiment was conducted over the course of 1 week. After discussing the study and communicating with respondents, those who agreed to participate in the experiment received 100 RMB (approximately equal to $14.25) of rewards; participants would then conduct 3–5 interventions in a week depending on their physical and mental state in order to compare the number of interventions needed to achieve maximum restorative experience. The two groups had no significant difference in the number of interventions conducted (Table 2).

Blood samples were collected before the first and after the last interventions. Considering the requests of patients and their families, no photos were taken during the experiment due to privacy.

Prior to the formal experiment, the purpose and process were introduced to the participants to decrease their nervousness and ensure their understanding of the experimental procedures. Participants were not allowed to communicate with each other until the experiment was complete. The pre-test stage included a questionnaire, physiological measurements, and an EEG baseline measurement. The questionnaire included basic information, SDS, and PANAS. Among them, the basic information section records

the gender, age, educational degree, income, and living environment of the respondents. During the physiological measurements, the respondents sat in the laboratory for 3 min before the first measurement was taken; BP and HR were then measured twice using an electronic sphygmomanometer, and there was a 1-min interval between the two measurements. After that, the portable EEG electrode was placed onto participants' foreheads for baseline measuring. Participants were asked to sit facing a white wall to temporarily exclude external visual stimuli. They were then asked to open their eyes and look at the wall for 1 min, and alternately close their eyes for another minute to determine their baseline brainwaves in order to identify the baseline of psychological stress before the experiment.

For visual stimulation, panoramic photos were displayed using the VR glasses. Each participant in the intervention group was asked to randomly view one selected panoramic photo for each category (BS, OGS, SOS, and CGS), for a total of four images each time. The participants in the control group were asked to view the photos of GrS only. Each photo lasted 1 min 20s and the total length of broadcast time was 5 min 20s. This time had been adjusted through preliminary experiments to ensure that the respondents could be fully immersed in each type of landscape without undue burden caused by prolonged exposure. The changes in brain waves would be recorded in real time when respondents in both groups viewed the panoramic photos.

During the post-tests, the respondents would give preference and PRS scores for each type of environment and fill out the PANAS once again. During this time, the BP and HR were measured twice again using an electronic sphygmomanometer with a 1-min interval between the two measurements (Figure 2). It is worth noting that the experimental procedure of the last experiment was the same as that of the first, while the other interventions only recorded the changes of brain waves during the viewing of the photos.

TABLE 2 Distributions of the participants among the different times of interventions in the intervention group and control group.

Group	Times of intervention (No. of the participants)		
	Three-time interventions	Four-time interventions	Five-time interventions
Intervention group	11	10	11
Control group	10	15	6
Significance of difference (Sig.)	95% C.I. (−12.17, 12.84), $T = 0.11$, $p = 0.919$		

Statistical analysis

The study used SPSS 17.0 (Statistical Package for the Social Sciences version 17.0) software to conduct the statistical analysis. First, the independent sample *T*-test was conducted on the demographic information of participants in the intervention group and the control group to examine whether a significant difference existed between the two groups, so as to ensure that the demographic information did not interfere with differences in experimental data between the two groups. Similarly, the initial levels of depression (SDS) in both groups were also tested to examine the differences between groups.

To understand the difference in preference of participants for the five landscape types, the study firstly used the independent samples *T*-test to analyze the difference of participants' preferences between the intervention group (viewed different types of blue and green spaces) and control group (viewed gray space). And then, arithmetic means and ANOVA with *post hoc* tests were used to analyze the difference in preferences among the different types of blue and green spaces. The psychophysiological restoration potentials of the environmental spaces between the two groups during the pre-tests and post-tests were mainly examined by the

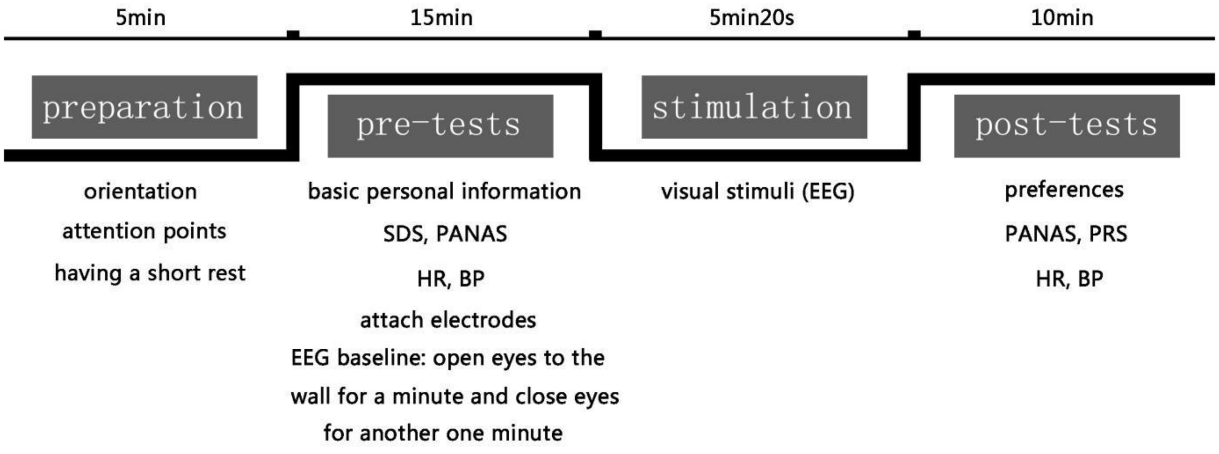

FIGURE 2
The study procedure within one experimental intervention and the corresponding time used within each stage.

paired *T*-test, using data collected from the PANAS, HR, and BP. At the same time, in order to test the differences in restoration levels between the two groups, an independent sample *T*-test was conducted to show the degree of the restoration of PANAS, HR, BP, and PRS. Groups were regarded as grouping variables, while the restoration differences before and after the experiment were regarded as the test variables. The arithmetic means and ANOVA with *post hoc* tests were conducted to show the restoration differences of PRS and EEG among different landscape types due to the expression of restoration ability and its significance.

The paired *T*-test was used to examine the differences in landscape preferences and psychophysiological restoration of patients in both groups under different intervention periods (times). Taking into account the external interference during the week-long experimental procedures, the study compared significant differences in the variation of psychophysiological indicators between the first and last experiments instead of the post-tests results only. In order to further explore the best intervention effect in a week and regarding the number of interventions as the classification criteria, the relaxation levels in brain waves within each intervention in the intervention group and the control group were expressed by calculating the mean values, respectively.

Goodness-of-fit of the models was assessed by Pearson's Chi-square and deviance tests to ensure the models fit the data adequately.

Results

The results showed that there were no significant differences in demographic information between the respondents in two groups, including gender ($p = 0.54$), age ($p = 0.60$), education degree ($p = 0.57$), income ($p = 0.34$), and living environment ($p = 0.14$). In addition, there was no significant difference between the two groups in the Self-Rating Depression Scale (SDS) ($p = 0.92$, mean value of the intervention group = 50.23, mean value of the control group = 50.52).

The most preferred type of environment within cancer patients based on comparative analysis of intervention group and control group

The results of the independent sample *T*-test showed that there was a significant difference in preferences between the intervention group and control group ($p < 0.01$). The arithmetic mean of the preference level of patients for the BS and GS in the intervention group was 4.44, while that for GrS in the control group was 0.84. In addition, there were also significant differences in the preferences of participants in the intervention group for BS and GS ($p < 0.01$). Results showed that BS was the most significantly preferred landscape type (mean values = 4.97 ± 1.00), followed by OGS (mean values = 4.66 ± 1.00), SOS (mean values = 4.34 ± 1.23), and CGS (mean values = 3.78 ± 1.26; Figure 3).

The differences in psychological and physiological restoration of cancer patients in two groups among different types of environment

It was found that for both the intervention group and the control group, the positive emotions (PANAS POS) of the

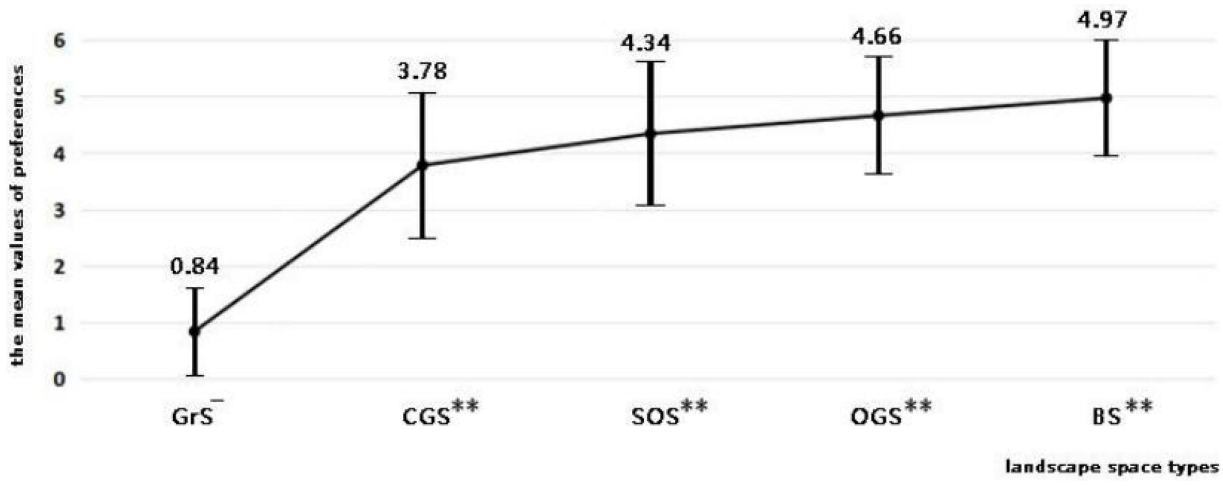

FIGURE 3
Mean values of participants' preferences for different landscape space types. I. GrS refers to the gray space. CGS refers to the closed green space landscape. SOS refers to the semi-open green space landscape. OGS refers to the open green space landscape. BS refers to the blue space landscape. II. — refers to the reference landscape. ** refers to the significant difference between the landscape and the reference landscape ($p<0.01$).

participants increased significantly after the visual stimuli, and the negative emotions (PANAS NEG) decreased significantly. Through the comparison between the two groups, their changes in positive emotions were significantly different, and the restoration level of the intervention group was significantly higher than that of the control group. Although there was no significant difference in negative emotions, the landscapes in the intervention group greater reduced negative emotions than the gray landscape in the control group (Table 3). For PRS, the results of the arithmetic means and ANOVA with *post hoc* tests showed that the BS had the significantly strongest potential to increase perceived restorativeness of the respondents, followed by OGS, SOS, and CGS, with the GrS having the least potential.

For the HR and BP indicators, except for the significant reduction of the HR in the intervention group during the post-tests ($p < 0.01$), there were no other significant differences between the two groups. For EEG, based on the arithmetic means and ANOVA with *post hoc* tests, the participants in the intervention group presented a greater trend of relaxation after the visual landscape stimuli than the open eye stage during the baseline measurement. The EEG alpha waves were the highest when the respondents' eyes were closed in the intervention group, and mean values of relaxation in the OGS, CGS, BS, and SOS were higher than that in the open eye stage. These differences were significant. For the control group, the EEG alpha wave value was the highest in the closed eye stage, followed by the open eye stage, and finally the visual stimuli stage (the gray space, GrS; Table 3).

The timeliness of psychophysiological restoration within cancer patients under multiple-time intervention in a week

Considering the large variation in the intervals of blood collection, the experiment did not conduct further analyses of the NLR level of participants in order to avoid result bias. While the results showed that the self-reported depression level of both groups decreased significantly after 1 week of visual stimulation intervention ($p < 0.01$), the level of perceived restoration (PRS) and landscape preference for the gray space was significantly decreased. Although the levels of the perceived restoration (PRS) and landscape preference also decreased after viewing the green and blue spaces, the changes were not significant. Moreover, the preference and the perceived restoration of respondents for the blue scape were slightly increased, and slightly reduced in the green space landscape. The level of negative emotion reduction by landscape stimulation was significantly different after 1 week of intervention ($p < 0.01$), and the ability of landscape to reduce

TABLE 3 The results of the *T*-test and ANOVA (mean values±standard deviation) concerning the effects of one visual stimulation on psychological and physiological restorative indicators of patients and the differences between the two groups.

	The intervention group			The control group		
	Pre-tests	**Post-tests**	**MD**	**Pre-tests**	**Post-tests**	**MD**
PANAS POS[a]	25.06 ± 6.84	30.88 ± 6.13	−5.82 ± 5.12[b]	19.71 ± 4.01	22.55 ± 5.19	−2.84 ± 4.82[b]
PANAS NEG	15.53 ± 5.30	11.28 ± 2.62	4.25 ± 3.97[b]	16.94 ± 5.27	12.97 ± 2.20	3.97 ± 4.15[b]
PRS	68.16 ± 10.50 (OGS) 66.47 ± 15.40 (SOS) 56.78 ± 17.08 (CGS) 78.22 ± 14.41 (BS)			12.39 ± 6.46 (GrS)		
			Post hoc: BS[b] > OGS[b] > SOS[b] > CGS[b] > GrS[−]			
Heart rate (HR)	75.08 ± 12.81	72.39 ± 13.54	2.69 ± 4.41[b]	75.89 ± 13.47	74.98 ± 11.90	0.91 ± 4.78
Diastolic blood pressure (DBP)	70.86 ± 10.80	71.31 ± 9.89	−0.45 ± 4.99	75.32 ± 10.89	74.10 ± 9.70	1.22 ± 3.62
Systolic blood pressure (SBP)	113.63 ± 16.26	114.58 ± 14.23	−0.95 ± 8.15	121.71 ± 19.06	119.18 ± 16.94	2.53 ± 7.49
EEG (*10^{-2})	6.61 ± 1.33 (open eyes) 12.39 ± 7.02 (closed eyes)			8.82 ± 4.88 (open eyes) 9.40 ± 5.33 (closed eyes)		
		7.36 ± 1.90 (OGS) 6.83 ± 1.36 (SOS) 6.94 ± 1.37 (CGS) 6.86 ± 1.47 (BS)			8.17 ± 4.16 (GrS)	
	Post hoc: closed eyes[−] > OGS[b] > CGS[b] > BS[b] > SOS[b] > open eyes[b]			*Post hoc*: closed eyes > open eyes > GrS		

I. MD refers to the mean difference between the pre-tests and the post-tests. II. GrS refers to the gray space. CGS refers to the closed green space landscape. SOS refers to the semi-open green space landscape. OGS refers to the open green space landscape. BS refers to the blue space landscape. III. — refers to the reference landscape.[a]Refers to the significant difference of MD between the intervention group and the control group.

[b]Refers to the significant difference between the landscape and the reference landscape ($p < 0.01$) or the significant difference between the pre-tests and post-tests. PANAS POS.

negative emotions decreased after 1 week of intervention. In addition, compared with the first experiment, there were no significant differences in the restoration of physiological indicators in both groups after several interventions of landscape stimuli during a week. After 1 week of intervention, the effects of blood pressure reduction and positive emotion promotion of the intervention group were slightly improved, and the ability to decrease the HR was slightly reduced, while the opposite was true for the control group. With the increase in intervention times, the ability of different landscapes to sooth mental stress (EEG) was weakened (Table 4).

The mean values of alpha brain waves showed that through repetitive visual interventions, the relaxed state of participants in the intervention group inclined to the highest level until the third intervention in a week. This indicates that three times a week may be the most suitable frequency to result in the highest level of relaxation. It may be better for cancer patients to be in contact with the natural environment three times a week rather than multiple times (Figure 4).

Discussion

In order to account for the fact that cancer patients were rarely studied in previous research, and for a lack of comparison of preferences and recovery effects between long-term and short-term experiments, the current study mainly examined the preferences of patients with esophageal and/or gastrointestinal cancer for five types of environment and the differences in their recovery in the short term and long term.

The preferences of different types of landscape

According to the arithmetic means and ANOVA with *post hoc* tests, the participants had the highest preference for BS, followed by GS, while GrS received the lowest preference. This suggests that compared with the gray space common in urban settings, natural environments of blue and green spaces are generally welcomed and appreciated by cancer patients, which is in line with previous conclusions (Jorgensen and Anthopoulou, 2007; Ibarra et al., 2017). Humans evolved in nature, and they prefer nature no matter the age and culture (Kaplan and Yang, 1990; Meidenbauer et al., 2019). This preference also applies to cancer patients, and has also been found to improve their cognitive performance (Ulrich et al., 1991). Blue space can give cancer patients a sense of being far from urban life by providing a serene environment and creating opportunities to meet their hydrophilic nature.

For the green space, it was found that the open green space was the most preferred, followed by the semi-open green space and the closed green space. This is in line with previous studies as well (Giergiczny et al., 2015; Ebenberger and Arnberger, 2019). However, varying opinions do exist. Wang et al. (2019) found a

TABLE 4 The results of the paired *T*-test examining the various psychophysiological indicators between the first and the last experiments (one-week period).

	SDS		PRS		PANAS POS[a]		PANAS NEG[a]	
	Intervention	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**	**Control**
First experiment	50.23	50.52	67.41	12.39	5.81	2.84	−4.25	−3.97
Last experiment	41.87	44.07	67.08	9.39	6.66	1.61	−2.19	−1.45
Significance of difference (Sig.)	<0.01	<0.01	n.s.	0.04	n.s.	n.s.	<0.01	<0.01

	HR[a]		Diastolic blood pressure (DBP)[a]		SBP[a]		EEG (*10^{-2})	
	Intervention	**Control**	**Intervention**	**Control**	**Intervention**	**Control**	**Intervention**	**Control**
First experiment	−2.69	−0.90	0.45	−1.23	0.95	−2.53	7.00	8.17
Last experiment	−1.67	−1.92	−0.17	0.13	−1.47	−2.00	7.63	7.48
Significance of difference (Sig.)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

	Preferences	
	Intervention	**Control**
First experiment	4.44	0.84
Last experiment	4.30	0.42
Significance of difference (Sig.)	n.s.	<0.01

[a]I. means that the study tested the significant differences of the variations in the first and the last experiments instead of the differences of the psychophysiological result only. II. n.s. means that there is no significant difference.

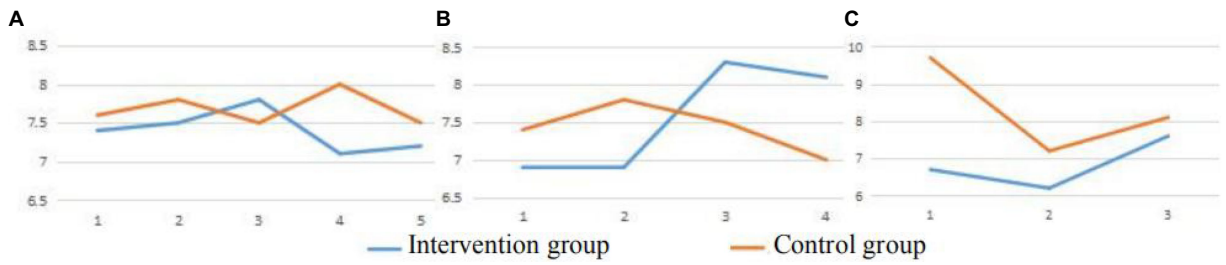

FIGURE 4
Mean values of Alpha brain waves. **(A)** The mean values of Alpha brain waves across five interventions. **(B)** The mean values of Alpha brain waves across four interventions. **(C)** The mean values of Alpha brain waves across three interventions.

positive correlation between plant number and preference, while Gao et al. (2019b) found that semi-structural green space was the most popular due to the tendency of untidy feelings that complex vegetation structure provides and the lack of security in open space. Some reasons for the differences in findings between this study and previous studies follow. On the one hand, this study used VR with panoramic 3D photo intervention, which is different from the traditional field survey and photo elicitation experiments. The immersion of VR can not only reflect the real situation on demand indoors, but also possibly shields the interference of other factors, which could be of positive significance to the results to reflect the true preference of the participants. On the other hand, preference is not only related to the features of landscape, but also to human attributes (Maulan and Miller, 2006). Cancer patients with activity inconvenience needed a greater sense of security and social care, as well as opportunities for appropriate activities. In this study, the open green spaces provided cancer patients with visual accessibility and therefore brought a sense of security, just as one participant mentioned "I can see everything with a wide view here." Compared with the complex structure of other types of green spaces, open green space does not require much attentional or cognitive effort because ground vegetation is one of the most important elements affecting landscape preferences (Nielsen et al., 2012). The tidy short-cut lawn may provide the patients with a visible sense of management and social care, and was described as "the lawn is trimmed and tidy" and "the lawn seems comfortable." Furthermore, research showed that open green spaces are more conducive to active recreational activities including physical exercise (Boxall and Macnab, 2000; Eriksson et al., 2012). Therefore, the open green space in this study might meet the needs of cancer patients and thus was generally welcomed.

The differences in psychophysiological restoration of cancer patients among different types of environment

The study found that the positive effect of nature on psychological health was significantly higher than that of gray space. This may be due to the fact that natural space gives cancer patients a sense of consistency, e.g., harmony and relatedness to themselves (Sevenant and Antrop, 2009; Peschardt and Stigsdotter, 2013). Most participants in this study lived in rural areas. They mentioned that the natural landscape was similar to the environment in which they lived, and it invoked a pleasant feeling. It is in line with their instinctive judgment that natural space is suitable for survival and prosperity, thus achieving psychological well-being (Ulrich, 1977; Kaplan et al., 1998). It is worth noting that the psychological indicators of the patients in the gray space, such as emotion and perceived restoration, also showed a certain improvement. This might indicate that cancer patients can gradually calm themselves during daily life without any intervention, but the natural environment can increase the ability of psychological restoration and emotional recovery. In addition, the results of this study showed that the participants had the highest level of perceived restoration in the blue space, followed by green space, and finally in the gray space, which is exactly the same as the preference trend. The blue space is not only the most popular environment, but also the most beneficial to the improvement of the patients' perceived restoration, followed by the open green space (Appleton, 1975). These spaces seem to be quite different from the common landscapes of daily urban space and can give cancer patients the feelings of being far away from the city and medical treatment. The beautiful bodies of water and the manicured large lawn are examples of the prospect-refuge theory, which describes a landscape that is open and without place for predators to hide (Appleton, 1975). These environments are popular and have restorative functions. Moreover, in line with the attention restoration theory (ART), the low complexity of blue space and open green space can provide attractive scenery while reducing energy consumption to alleviate mental fatigue (Joye and van den Berg, 2011), helping the cancer patients to deal with natural characteristics more easily (Joye et al., 2016), and therefore reducing the consumption of psychophysiological energy.

Interestingly, this study found that despite the preferences and benefits of psychology, the recovery of physiological indicators was not as significant. This is probably due to the fact that the change in physiological indicators was not as significant as psychological indicators, so that 5 min and 20s of landscape stimulation could not be adequate enough to produce a significant physiological response. Chang et al. (2008) found that the EEG alpha waves of a simulated landscape with a restorative function

were increased compared to other simulated landscapes. As an indicator of relaxation, alpha brain waves showed that patients' relaxation was the highest when they closed their eyes, even higher than in the landscape stimulation stage. This is somewhat inconsistent with previous studies (Tyrväinen et al., 2014), although closed eyes can improve the degree of relaxation of the body and mind. Considering no work was assigned to the cancer patients in the eyes closed stage, the visual stimuli and the viewing of the white wall might have given the participants a sense of burden and thus was not conducive to their relaxation. This might be attributed to the difference between cognitive load and no cognitive load, as it is only when the eyes are open that people can infer a degree of cognitive workload (Onishi and Hagawara, 2017). Compared with the eyes-closed conditions, other brainwaves could be activated separately during the eyes-open conditions (Barry et al., 2007). Therefore, further examination and consideration is required in choosing eyes-closed conditions as baseline conditions and physiological indicators in future studies. However, the relaxation level in the landscape stimuli stage was higher than that of patients in the eyes open stage, which suggested that natural landscape can bring certain physiological and psychological benefits compared with the general state. After all, since a variety of visual stimuli filled the patients' time when their eyes were open during the average day (Onishi and Hagawara, 2017), they can receive mental restoration through nature interventions, which indicated that VR can be applied as a useful and feasible tool for restorative experience with cancer patients.

The timeliness of psychophysiological restoration

This study proved that repetitive natural landscape interventions within a week could enhance the physical and psychological restoration potential of patients. Previous studies have also examined the intervention terms in different landscapes, but instead focused only on the length change of one experiment. For example, Ulrich et al. (1991) demonstrated the positive effect of nature on physiological indicators through a 10-min nature intervention. Furthermore, the participants did not focus on or include cancer patients, or include varying periods of interventions. Shanahan et al. (2016) proposed the benefits of a 30-min natural environment for hypertensive patients, but the impact of time spent in nature on mental health was relatively unexplored for cancer patients (Trostrup et al., 2019). It was demonstrated that long-term exposure to natural space had more advantages than short-term exposure, which might be due to the accumulation of natural rehabilitation benefits. Three times a week proved to be the best intervention frequency for cancer patients to relax, indicating that this frequency of intervention met their relaxation requirements without producing a negative burden and emotion over time, such as boredom. Based on these important findings and considering that the cooperation of cancer patients (physical condition, objective influence, etc.) is also necessary for a long-term study, exploration is still required to determine how long this effective rehabilitation can last in the future.

Limitations and implications for further research and landscape plans

To a certain extent, although this study filled a gap existing in previous studies of landscape preference on the psychophysiological restoration of cancer patients within long-term interventions, it also has some inadequacies. First, although considering the high incidence and mortality of esophageal and gastrointestinal cancer diseases (Anderson et al., 2019; Zhao and Lim, 2020), other kinds of cancer patients were not included. Demographic characteristics could also affect the experimental results of cancer patients (Holm et al., 2012), so subsequent studies could focus on cancer patients with specific demographic characteristics. Second, more quantitative measures of immune indicators are needed. One of the important positive links between nature and health is the increase in immune ability (Kuo, 2015). However, there has not been a study conducted to explicitly link green and blue spaces in cities to improvements of the human immune system. Third, perception and preference are the result of multiple sensory combinations (Subiza-Pérez et al., 2019). Future experiments can incorporate other senses, such as audio, tactus, and olfaction, which might change the results of the study. Fourth, as for the experimental design, HR were only measured in pre-and post-test stages in our study. It is better and more accurate to conduct a real-time monitoring during the whole experiment in further research. Moreover, participants' prior experience of using VR equipment should be asked in further study, since it may relate to their adaptation to VR and affect the results.

Conclusion

This paper explored the esophageal and gastrointestinal cancer patients' preference and restoration potential in various landscapes under different intervention times by VR. Some main conclusions were obtained. First, the blue and green spaces were more popular among cancer patients than the gray space (hospital environment). They were also beneficial to the psychological health (e.g., emotion and perceived restoration) and recovery of some physiological indicators (e.g., HR). Second, the cancer patients showed a high degree of relaxation when they had nature interventions in spite of the peak level of relaxation during the eyes-closed period in the EEG baseline measuring stage. Finally, three times a week seems to be the most suitable frequency for cancer patients to be exposed to nature for psychological health. These conclusions provide a theoretical basis and interdisciplinary guidance for the construction of cancer-patient-oriented environments. For example, blue space and open green space could not only satisfy the preference of patients, but also be conducive to their psychophysiological recovery. More attention should be thus paid to the appropriate increase of blue space and the use of open green space in the improvement of hospital and rehabilitation community landscapes. In addition, for patients whose movements are restricted, they can receive the benefits of nature through viewing natural environments through

their hospital windows, while for those who are completely incapacitated, VR may be utilized to conduct natural interactions three times a week to improve physical and mental restoration and reduce the stress of medical treatments such as chemotherapy.

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 authors.

Ethics statement

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the College of Landscape Architecture and Arts, Northwest A&F University. Written informed consent to participate in this study was provided by the patient/participants.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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What motivates farmers to adopt low-carbon agricultural technologies? Empirical evidence from thousands of rice farmers in Hubei province, central China

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Low-carbon agriculture is essential for protecting the global climate and sustainable agricultural economics. Since China is a predominantly agricultural country, the adoption of low-carbon agricultural technologies by local farmers is crucial. The past literature on low-carbon technologies has highlighted the influence of demographic, economic, and environmental factors, while the psychological factors have been underexplored. A questionnaire-based approach was used to assess the psychological process underlying the adoption of low-carbon agricultural technologies by 1,114 Chinese rice farmers in this paper, and structural equation modeling (SEM) was empirically employed to test our theoretical model. The results indicated that farmers' low-carbon production attitude and behavioral efficiency perception directly and positively affected the adoption of low-carbon agricultural technologies and indirectly affected it via low-carbon production intention. Besides, production implementation cost and socio-environmental factor could moderate the direct effects of low-carbon production attitude, behavioral efficiency perception, and low-carbon production intention on farmers' adoption of low-carbon agricultural technologies. In this respect, socio-environmental factor yielded more significant moderating effects. Additionally, this research provides policy implications for promoting low-carbon agricultural technologies in developing countries and regions.

KEYWORDS

low-carbon agriculture, low-carbon technology, structural equation modeling, psychological mechanism, rice farmer

Introduction

A low-carbon economy represents a novel approach implemented by many countries for economic development and protection against global warming (Jiang et al., 2010; He, 2016). As a developing country, China pledged to reduce carbon dioxide emissions per unit of GDP by 60–65% by 2030 compared with 2005 and included this as a restrictive indicator in the medium and long-term planning of national economic and social development at the Paris Climate Change Conference (Yang and Teng, 2018). Notwithstanding that excessive industrial greenhouse gas emissions are one of the leading causes of global warming, agricultural greenhouse gas emissions also threaten the global climate. According to the "Special Report on Climate Change and Land" published by the Intergovernmental Panel on Climate Change, agriculture, forestry, and other land use account for nearly 23% of the greenhouse gas emissions of human activities globally (IPCC, 2019), and the problems of chemical fertilizers and pesticide residues, soil compaction, food, and environmental safety caused by high-carbon agriculture have exacerbated (Maraseni et al., 2018). In fact, promoting low-carbon agricultural technologies can effectively mitigate global warming. Importantly, the decarbonization of farmers' practices is key to promoting the low-carbon development of agriculture (Scarlat et al., 2015). Thus, investigating the psychological mechanism underlying farmers' adoption of low-carbon agricultural technologies is of great theoretical and practical significance for developing countries to protect against global warming and foster sustainable agricultural economics.

Extant research on low-carbon production generally includes three aspects. The first one is the evaluation of low-carbon agricultural production. For example, Bai et al. (2019) calculated the production efficiency of low-carbon agriculture from the perspective of carbon emissions and sequestration to explore the impact of climate change on agricultural production. Moreover, Liu et al. (2020) constructed an evaluation index system for low-carbon agricultural production based on supply capacity, resource utilization, environmental quality, ecosystem maintenance, and farmers' lives. The second aspect involves the determining factors associated with farmers' adoption of low-carbon technologies. By applying regression models, such as Logistic and Probit, scholars comprehensively assessed the effects of the demographic, family characteristics, environment, and risk factors on farmers' adoption of low-carbon technologies (Jain and Rekha, 2017; Liu et al., 2019; Zhang et al., 2019), and explored the consistency of low-carbon production intention and behavior regarding straw returning (Li et al., 2021b). Furthermore, studies have shown that low-carbon perception, value perception, and social norms significantly influence farmers' adoption of low-carbon agricultural technologies (Jiang et al., 2018; Yu et al., 2018). The last aspect is intervention policies for farmers' adoption of low-carbon technologies. A study pointed out that subsidies or a reasonable carbon tax contributed to reducing agricultural carbon emissions and promoting the development of low-carbon agriculture (Fan and Dong, 2018). Therefore, governments have the onus to actively promote low-carbon agriculture. Various measures (such as formulating subsidy policies for low-carbon agricultural production, constructing agricultural irrigation infrastructure, and promoting land-use rights transfer) can be undertaken by governments to foster low-carbon production among farmers (Pradhan et al., 2017; Zhu et al., 2018).

In some developing countries, low-carbon agricultural materials (such as soil testing formula fertilizer and biological pesticide) and technologies (such as intermittent irrigation and straw returning) with well-documented emission reduction effects have been gradually promoted in major agricultural production areas (Liu et al., 2019; Li et al., 2021b). However, the adoption rates of low-carbon agricultural materials and technologies remain low among farmers. Although farmers are willing, the adoption behavior is rarely observed, which is described as the phenomenon of "high intention—low behavior" (Vande Velde et al., 2018). Little emphasis has hitherto been placed on such psychological and behavioral phenomena, with most studies focused on the impact of demographic, economic, and environmental factors on farmers' adoption of low-carbon technologies (Jain and Rekha, 2017; Liu et al., 2019; Zhang et al., 2019). Interestingly, social media has an essential impact on farmers' adoption of low-carbon agricultural technologies (Yang et al., 2021), and farmers of the same clan usually participate in the same agricultural activities (Jiang et al., 2022). In addition, a psychological study showed that individual behavior is affected by environmental factors, and psychological factors such as cognition, emotion, and intention play an essential role (Strack et al., 2016). Accordingly, this paper intends to examine the psychological and situational factors that influence farmers' decision-making on adopting low-carbon technologies. Rice is widely acknowledged as a food crop that significantly emits greenhouse gases during its growth period (Maraseni et al., 2018), thus rice farmers were selected as the study subject in this study. In order to reduce greenhouse gas emissions from the production process of rice farmers, this study aims to address the following questions: (1) What are the psychological factors that determine the adoption of low-carbon technologies by rice farmers? (2) What is the influence mechanism of these factors on their adoption behavior? (3) How to effectively guide rice farmers to participate in low-carbon rice production? These answers provide the basis for developing countries to effectively promote low-carbon agricultural technologies to protect the global climate.

Theoretical background and hypotheses

Adoption of low-carbon technologies

The adoption of low-carbon technologies by rice farmers refers to the use of low-carbon agricultural materials and management measures to reduce agricultural greenhouse gas emissions and improve the agricultural ecological environment (Liu et al., 2020). In this paper, based on the actual situation of low-carbon rice production in Hubei province of China, low-carbon technologies with the best carbon emission reduction effects, namely two low-carbon agricultural materials (i.e., soil testing formula fertilizer and biological pesticide) and two field management measures (i.e., intermittent irrigation and straw returning), were selected based on the opinions of 20 agronomy and crop science experts.

Low-carbon production attitude

According to the theory of planned behavior (TPB), an attitude is a positive or negative evaluation of a given behavior (Ajzen and Fishbein, 1977), and a positive attitude can increase the probability of the behavior occurring (Li et al., 2021a). In this study, the low-carbon production attitude refers to rice farmers' cognition and evaluation of climate change, low-carbon agriculture, and environmental protection, including low-carbon cognition and environmental awareness. An increasing body of evidence suggests that the more positive attitude of farmers towards low-carbon production technologies, the more likely their behavioral intentions are to improve (van Dijk et al., 2016; Mingolla et al., 2019; Waseem et al., 2020). Besides, some studies highlighted that the positive attitude of farmers positively impacts their behavioral efficiency perception and production behavior. For example, Bagheri et al. (2019) indicated that farmers' attitude toward pesticides significantly affected their perception and behavior. Environmental awareness also positively affects their pro-environment production behavior (Zeng et al., 2019). Herein, rice farmers' behavioral efficiency perception was divided into two aspects: the value perception of economic and ecological benefits (i.e., value perception) and the self-efficacy of adopting low-carbon agricultural technologies (i.e., self-efficacy).

Accordingly, rice farmers' cognition and evaluation of climate change and low-carbon agriculture and their environmental awareness of soil, water quality, atmosphere, and other surrounding environments impact their intention and adoption of low-carbon technologies. Furthermore, there may be a close relationship between rice farmers' attitude toward adopting low-carbon technologies and the perceived efficiency of adoption behavior. Consequently, rice farmers' low-carbon production attitude (i.e., low-carbon cognition, environmental awareness) significantly affects their behavioral efficiency perception (i.e., value perception, self-efficacy), low-carbon production intention, and adoption of low-carbon technologies. The following hypotheses were proposed:

> H1a: Low-carbon cognition of rice farmers has a positive effect on their value perception.

> H1b: Low-carbon cognition of rice farmers has a positive effect on their self-efficacy.

> H1c: Low-carbon cognition of rice farmers has a positive effect on their low-carbon production intention.

> H1d: Low-carbon cognition of rice farmers has a positive effect on their adoption of low-carbon technologies.

> H2a: Environmental awareness of rice farmers has a positive effect on their value perception.

> H2b: Environmental awareness of rice farmers has a positive effect on their self-efficacy.

> H2c: Environmental awareness of rice farmers has a positive effect on their low-carbon production intention.

> H2d: Environmental awareness of rice farmers has a positive effect on their adoption of low-carbon technologies.

Behavioral efficiency perception

According to the rational behavior theory and TPB, individual behavior efficiency perception or perceived behavior control can predict behavioral intention and implementation (Schifter and Ajzen, 1985; Ajzen and Timko, 1986; McCaul et al., 1988; Adnan et al., 2019). Moreover, a stronger perceptual capability of individual behavior efficiency has been associated with a greater likelihood of behavioral intention (de Lauwere et al., 2012). Interestingly, it has been reported that the intention of rice farmers to adopt low-carbon agricultural technologies was positively affected by their perception of the rice planting experience (Li et al., 2021a). Besides, perceived

efficacy fostered farmers to produce in a pro-environment manners (Zeng et al., 2019). In this research, behavioral efficiency perception refers to rice farmers perceiving the effects of low-carbon agricultural technologies and their ability to implement them, including the value perception and self-efficacy. For example, during low-carbon rice cultivation, farmers may perceive the ecological value of low-carbon agricultural technologies to improve the environment and the convenience of using low-carbon agricultural materials. Traditional agricultural production technologies pollute the ecological environment and seriously threaten farmers' health due to pesticide residues in agricultural products. The pressure on farmers to protect their health drives their learning of low-carbon agricultural production technologies and the value of these technologies in improving the ecological environment and solving food safety problems (Vuong, 2021, 2022). Current evidence suggests that farmers are more likely to apply organic fertilizers if they perceive the ecological and economic value in reducing environmental pollution (Li and Wu, 2021). Meanwhile, the loss aversion of farmers can reportedly harm their behavioral perceptions due to the increased economic costs of sustainable management measures (Mingolla et al., 2019). Therefore, there may be a close relationship between farmers' perceived value and self-efficacy in the low-carbon production scenario.

On these grounds, rice farmers' value perception of low-carbon agricultural technologies (e.g., environmental value, economic value, emission reduction value), as well as self-efficacy (information acquisition, purchase of agricultural materials, labor-saving) may positively affect their low-carbon production intention and adoption of low-carbon technologies (Borges and Lansink, 2016). Consequently, rice farmers' behavioral efficiency perception (i.e., value perception, self-efficacy) significantly affects their low-carbon production intention and adoption of low-carbon technologies. The following hypotheses were proposed:

> H3a: Value perception of rice farmers has a positive effect on their self-efficacy.

> H3b: Value perception of rice farmers has a positive effect on their low-carbon production intention.

> H3c: Value perception of rice farmers has a positive effect on their adoption of low-carbon technologies.

> H4a: Self-efficacy of rice farmers has a positive effect on their low-carbon production intention.

> H4b: Self-efficacy of rice farmers has a positive effect on their adoption of low-carbon technologies.

Low-carbon production intention

Based on the TPB, individual behavioral intention positively affects the occurrence of behavior (Ajzen, 1991). A positive correlation has been documented between farmers' production intention and actual production behavior (Lalani et al., 2016). However, other studies suggested a paradox between farmers' behavioral intention and actual behavior; although farmers may have a firm behavior intention, it is not necessarily translated into the actual production behavior (Sharifzadeh et al., 2017; Hyland et al., 2018; Vande Velde et al., 2018). This discrepancy between intention and behavior may be caused by internal and external factors, such as production implementation cost and socio-environmental factor. Therefore, there may be a positive or negative causal effect between rice farmers' low-carbon production intention and adoption of low-carbon technologies (Ajzen, 1991; Borges and Lansink, 2016). The following hypothesis was proposed:

> H5: Low-carbon production intention of rice farmers may significantly affect their adoption of low-carbon technologies.

Production implementation cost and socio-environmental factor

According to the above analysis, farmers' attitude, behavioral efficiency perception, and intention will influence their adoption of low-carbon technologies. However, some studies have emphasized that farmers' behavioral intention may not translate into actual behavior under the influence of some moderating variables (Hagger et al., 2002; Han, 2015). This phenomenon reveals that the decision of farmers to adopt low-carbon production is influenced by a series of factors, such as economic factors (Lo, 2014), policy conditions (Malawska and Topping, 2016), and family background (Aydogdu and Yenigün, 2016; Zhou et al., 2020). This paper mainly investigated the impact of production implementation cost and socio-environmental factor on rice farmers' adoption of low-carbon agricultural technologies.

First, production implementation cost indicates the cost of adopting low-carbon agricultural technologies, including traditional farming habit and risk tolerance. Low-carbon

agricultural materials and production technologies may increase investment and risk, leading to enhanced production costs and discouraging farmers from adopting low-carbon production (Liu et al., 2021). Meanwhile, the environmental value of adopting these low-carbon agricultural technologies cannot be directly exchanged for monetary value because of the lack of a new eco-surplus culture where the value created for the environment is rewarded with money (Vuong, 2021), which may reduce farmers' enthusiasm for adoption. An increasing body of evidence suggests that economic compensation improves farmers' environmental attitude (Burton et al., 2007; Koundouri et al., 2009). Besides, economic compensation can directly improve farmers' attitude and indirectly affect their behavior by moderating the intensity of their behavioral intention (Castillo et al., 2021). Meanwhile, Liu et al. (2021) found that government subsidies positively moderated the effect of farmers' risk perception on adopting groove ridge planting and subsoiling. Therefore, the production implementation cost may affect farmers' adoption of low-carbon technologies by moderating their low-carbon production attitude, behavioral efficiency perception, and low-carbon production intention.

Second, it is widely acknowledged that farmers live in social groups, and their behavior is affected by the territorial socio-environmental factors. In this study, emphasis was placed on the cultural background and social environment of rice farmers, including the cultural background of small-scale farmers, government-led promotion, and group effect. Some researchers found that external environmental factors can change farmers' behavior (Hagger et al., 2002). For example, significant differences were found between farmers' perception level and decision-making behavior in different social organizations (such as cooperatives) (Han, 2015). At the same time, farmers' social norm positively moderated the effect of individual norm on their organic fertilizer application behavior (Lo, 2014). Moreover, the perceived social pressure of individual farmers was closely related to their attitude and intention (Aydogdu and Yenigün, 2016; Malawska and Topping, 2016). Undeniably, if farmers obtain relevant information but remain skeptical about its significance, they may still not use or adopt low-carbon agricultural technologies. Therefore, the trust associated with the group effect plays an important role in the mindsponge-based information process of farmers (Vuong and Napier, 2015; Vuong et al., 2022). The above analysis confirms that local socio-environmental factors affect farmers' attitude, perception, and intention toward low-carbon technologies for agriculture. Accordingly, the following hypotheses were proposed:

> H6a: Production implementation cost moderates the effect of rice farmers' low-carbon production attitude on their adoption of low-carbon technologies.

> H6b: Production implementation cost moderates the effect of rice farmers' behavioral efficiency perception on their adoption of low-carbon technologies.

> H6c: Production implementation cost moderates the effect of rice farmers' low-carbon production intention on their adoption of low-carbon technologies.

> H7a: Socio-environmental factor moderates the effect of rice farmers' low-carbon production attitude on their adoption of low-carbon technologies.

> H7b: Socio-environmental factor moderates the effect of rice farmers' behavioral efficiency perception on their adoption of low-carbon technologies.

> H7c: Socio-environmental factor moderates the effect of rice farmers' low-carbon production intention on their adoption of low-carbon technologies.

Theoretical framework

Overall, from the perspective of the psychological mechanism of information processing, rice farmers' adoption of low-carbon technologies results from a mindset change where the perceived value of such behavior is integrated into their mindset, which can be seen as a mindsponge-based information process (Vuong and Napier, 2015). Indeed, rice farmers adopt low-carbon technologies when subjectively perceived as beneficial. Otherwise, the idea will be rejected. A positive net value is obtained after farmers consider all related costs and benefits that they are aware of, which results in a change of their intention into actual behavior when the net perceived value of the act reaches a certain threshold (individual-specific). Accordingly, rice farmers' mindset about the perceived value of adopting low-carbon agricultural technologies can be changed by improving their low-carbon cognition and environmental awareness. Meanwhile, through the mindsponge-based information process, relevant information about the value perception and self-efficacy of low-carbon agricultural technologies is integrated into rice farmers' mindset, leading to changes in their adoption intention and behavior. Moreover, the production implementation cost and socio-environmental factor play key

roles in rice farmers' adoption intention turning into behavior by influencing the perceived costs and benefits.

Consequently, the theoretical framework of this research was established (**Figure 1**).

Materials and methods

Data collection

Hubei province, well-established as the top rice-producing region with the highest output in China, was used as the representative area for investigating Chinese rice farmers' adoption of low-carbon technologies. We conducted a questionnaire survey based on the theoretical model (see **Figure 1**) in three major rice-growing areas in Hubei province, encompassing 10 districts/counties: Zaoyang, Zhongxiang, and Zengdu in the north; Zhijiang, Gong'an, Qianjiang, and Chibi in the south; and Macheng, Xinzhou, and Wuxue in the east (see **Figure 2**). After these 10 cultivating districts/counties were chosen, the survey team randomly selected two to three towns in each district/county and two to three villages in each town. Then 20 rice farmers were randomly selected from the lists of villagers provided by the village officials. After excluding invalid questionnaires, 1,114 questionnaires were eligible for analysis, with the validity rate of 92.83%.

Questionnaire design

As mentioned earlier, this research investigated rice farmers' low-carbon production attitude in terms of low-carbon cognition and environmental awareness. Regarding rice farmers' low-carbon cognition, this study was based on the scales of Maloney et al. (1975), Guagnano et al. (1995), and Oliver and Rosen (2010). The measurement items were modified according to the research purpose. To fit the environmental characteristics of China, this paper measured rice farmers' environmental awareness from three dimensions: soil pollution, water pollution, and air pollution. The scales were based on the research results of Maloney et al. (1975), Dunlap et al. (2000), and De Groot and Steg (2009). Meanwhile, farmers' behavioral efficiency perception was studied in terms of value perception and self-efficacy. First, farmers' value perception was measured from three dimensions, namely environmental value, economic value, and emission reduction value. The measurement items of these three variables were based on the scale of Steg et al. (2014). Moreover, rice farmers' self-efficacy was based on the scale of Fielding et al. (2008), measured from three dimensions: access to information, purchase of agricultural materials, and labor-saving. The original measurement items were adjusted appropriately based on the current situation in rural China and the characteristics of rice farmers. Furthermore, in line with the Chinese rural culture, this paper designed the scales for rice farmers' low-carbon production intention and adoption of low-carbon technologies based on findings reported by Stern et al. (1999) and Folse et al. (2010).

To conform to the characteristics of Chinese rural culture, this paper assessed the production implementation cost from two aspects: traditional farming habit and risk tolerance. The traditional farming habit investigated the costs of transformation, including deep plowing habit and extensive production mode. Moreover, the risk tolerance included rice farmers' judgment on climate change risk and their risk preference for adopting low-carbon technologies. Furthermore, many small-scale rice farmers in China were managed by village committees. Therefore, the social environment factor was measured from three aspects: cultural background of small farmer, government-led promotion, and influence of group effect. Among them, the cultural background of smallholders included self-discipline consciousness and conservative mentality. Besides, the government-led promotion contained subsidy promotion and punishment regulation. Finally, the influence of group effect was associated with conformity psychology and convergence behavior.

After completing the draft of the questionnaire, the researchers revised it twice. First, the experts related to agronomy evaluated the rationality of the questionnaire, and the researchers adjusted the content according to the evaluation results. Next, a preliminary survey was conducted on representative rice farmers and village cadres, and the researchers modified the questionnaire measurement items according to the survey results. The final measurement items related to rice farmers' adoption of low-carbon technologies are shown in **Table 1**.

Methodology

Structural equation modeling (SEM) was constructed to empirically test the theoretical framework of farmers' adoption of low-carbon technologies. Besides, the mediating effect of low-carbon production intention was verified by causal steps approach, and the moderating effects of production implementation cost and socio-environmental factor were tested by hierarchical regression. The specific methods were described as follows:

Structural equation modeling

This study employed SEM to explore the latent relationships between rice farmers' adoption behavior and influencing factors (see **Figure 3**). SEM is composed of the measurement model and structural model. Equations (1) and (2) are measurement models used to test the relationships between latent variables (exogenous and endogenous latent variables) and observational variables. Equation (3) is a structural model that can test

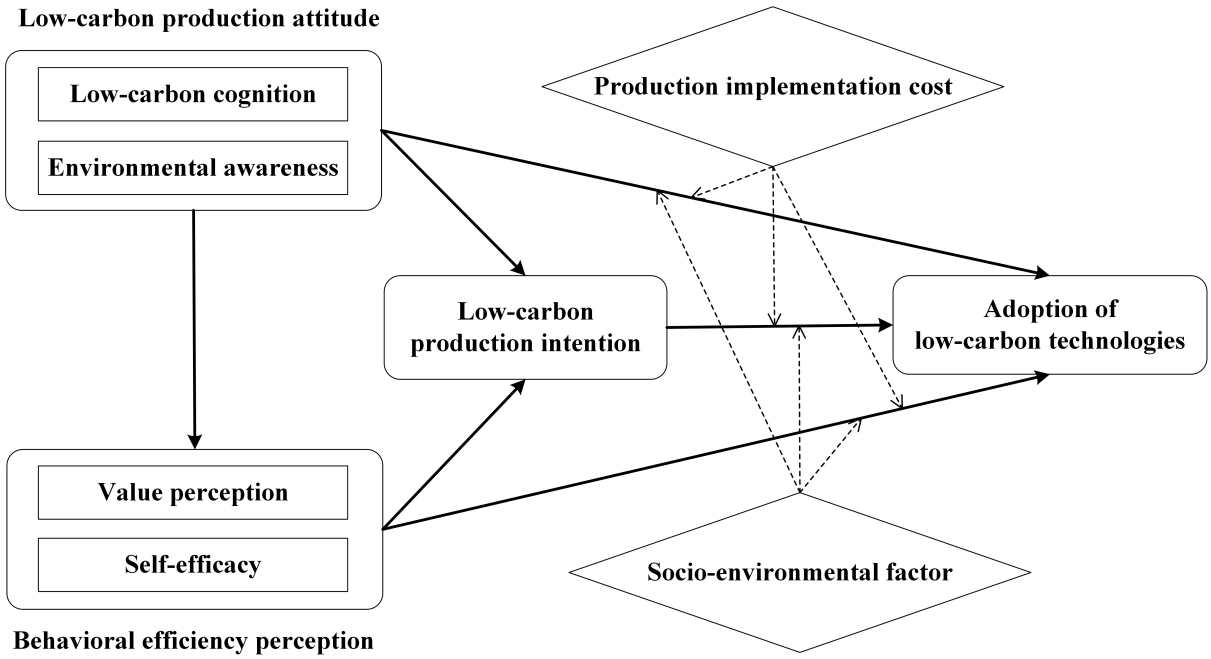

FIGURE 1
Theoretical framework of rice farmers' adoption of low-carbon technologies.

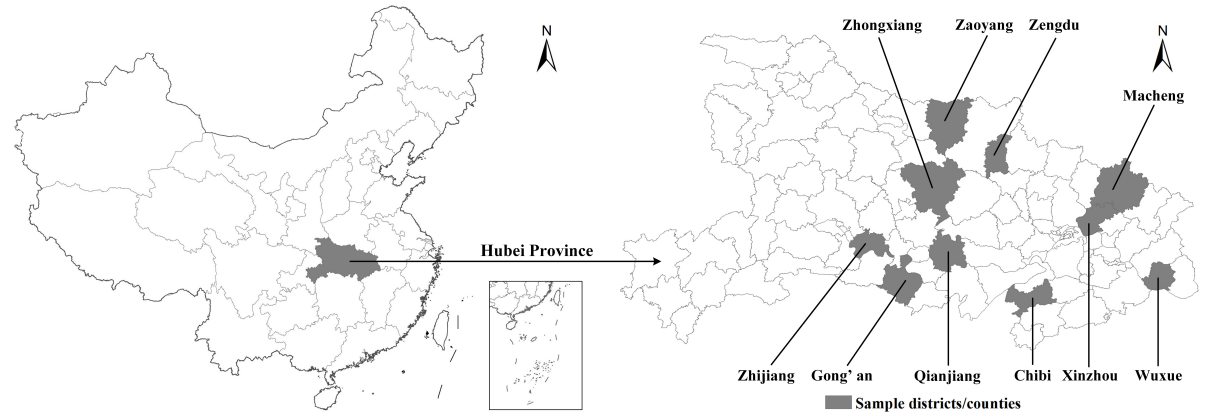

FIGURE 2
Survey region and sample distribution.

the causal effects between exogenous and endogenous latent variables.

$$X = \Lambda_X \xi + \delta \quad (1)$$

$$Y = \Lambda_y \eta + \varepsilon \quad (2)$$

$$\eta = B\eta + \Gamma\xi + \zeta \quad (3)$$

where X represents the exogenous latent variable vector, including rice farmers' low-carbon cognition, environmental awareness, value perception, and self-efficacy; ξ represents the observational variables of the exogenous latent variables; Y represents the vector of the endogenous latent variable, reflecting the low-carbon production intention and the adoption of low-carbon technologies; η represents the observational variables of the endogenous latent variables. Λ_X and Λ_y represent the correlation coefficient matrix between exogenous latent variables, endogenous latent variables, and their corresponding observational variables, respectively; δ and ε are the measurement error vectors of the exogenous and endogenous

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TABLE 1 Scales of rice farmers' adoption of low-carbon technologies and relevant variables.

Variable/dimension		Num.	Item	Range
Low-carbon cognition	Climate change	A1	True or False: (1) Excessive greenhouse gas emissions lead to a global average temperature drop. (2) Greenhouse gas is carbon dioxide. (3) Burning straw will not cause climate change. (4) Using chemical fertilizers will produce greenhouse gas emissions. (5) Climate change will threaten agricultural production.	0 = incorrect answers; 1 = correct answer; sum: 0 ∼ 5.
	Low-carbon technologies	A2	I know low-carbon agricultural technologies (such as intermittent irrigation and straw returning).	5-point Likert scale: 1 = strongly disagree;
	Low-carbon agriculture	A3	Low-carbon agriculture is a low-pollution, low-emission production method.	2 = disagree; 3 = neutrality; 4 = agree; 5 = strongly agree.
Environmental awareness	Soil pollution	B1	I will pay attention to the soil salinization and lack of organic matter on arable land.	
	Water pollution	B2	I will pay attention to the pollution of ponds and groundwater in the village.	
	Air pollution	B3	I will pay attention to air pollution and air quality.	
Value perception	Environmental value	C1	Using fewer chemical fertilizers and pesticides is good for the environment and soil.	
		C2	I must reduce environmental pollution from agricultural production.	
	Economic value	C3	Taking the lead in adopting low-carbon agricultural technologies will increase my income in the future.	
	Emission reduction value	C4	I think low-carbon agricultural technologies can effectively reduce agricultural greenhouse gas emissions.	
Self-efficacy	Access to information	D1	I can easily get information about low-carbon agricultural technologies.	
	Purchase of agricultural materials	D2	I can easily buy low-carbon materials such as soil testing formula fertilizers and biological pesticides.	
	Labor-saving	D3	Using low-carbon fertilizers and pesticides is very convenient and labor-saving for me.	
Low-carbon production intention	Promotion	Y1	I am willing to adopt the low-carbon rice production technologies and management measures if they are promoted.	
	New technologies	Y2	I am willing to try new agricultural technologies or management approaches.	
	Demonstration	Y3	I would like to adopt low-carbon rice production technologies if they are demonstrated.	
	Subsidy	Y4	I intend to adopt low-carbon agricultural technologies if the government grants ecological subsidies.	
Adoption of low-carbon technologies	Agricultural material application	Z1	I use soil testing formula fertilizer in the process of rice planting.	5-point Likert scale:
		Z2	I use biological pesticides in the process of rice planting.	1 = never; 2 = seldom; 3 = sometimes; 4 = usually; 5 = always.
	Field management	Z3	I irrigate intermittently in the process of rice planting.	
	Waste disposal	Z4	I return the straw to the field when the rice is harvested.	
Traditional farming habit	Deep plowing habit	E1	I always profoundly plow rice fields.	5-point Likert scale:
	Extensive production mode	E2	There is no need to change the extensive production mode that relies on overusing fertilizers and pesticides.	1 = strongly disagree; 2 = disagree; 3 = neutrality; 4 = agree; 5 = strongly agree.

(Continued)

TABLE 1 (Continued)

Variable/dimension		Num.	Item	Range
Risk tolerance	Risk level	F1	I think extreme weather phenomenon has a significant impact on rice yield.	
	Risk preference	F2	If all farmers adopt low-carbon agricultural technologies, I think they will be more reliable.	
Small farmer cultural background	Self-discipline	G1	Even if the government provides a suggested farming method, I will cultivate the land as I wish.	
	Conservation	G2	I wouldn't believe in new agricultural technologies easily.	
Government-led promotion	Subsidy	H1	I won't adopt low-carbon agricultural technologies without government subsidies.	
	Punishment	H2	Under the strict penalties of the government, I will return the straw to the field.	
Group effect	Conformity	I1	I will follow most people in adopting low-carbon agricultural technologies.	
	Convergence	I2	My behavior is more easily influenced by those around me.	

There are five questions that examine the objective perception of rice farmers on climate change (A1).

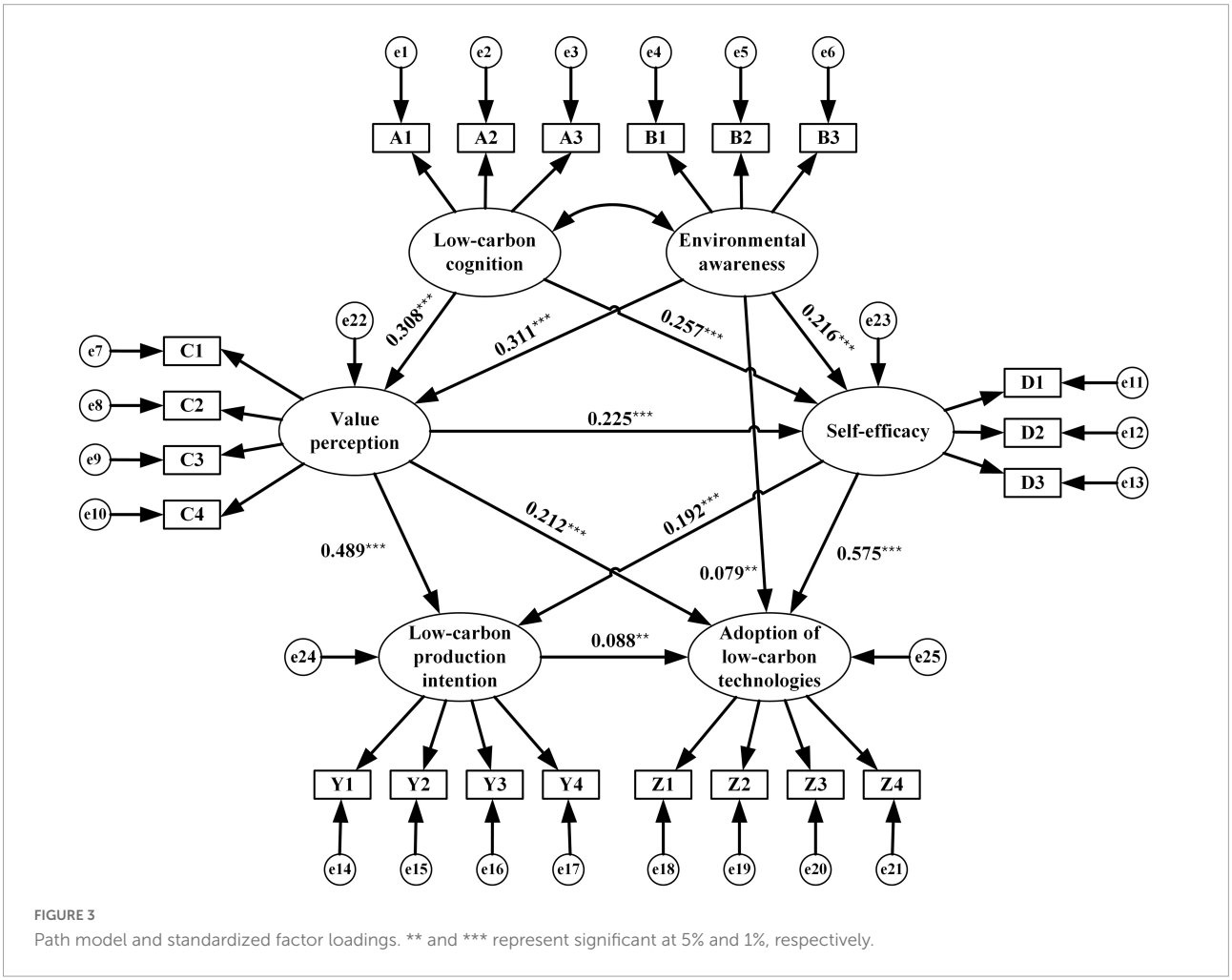

FIGURE 3
Path model and standardized factor loadings. ** and *** represent significant at 5% and 1%, respectively.

observational variables; B represents the matrix of structural coefficients among endogenous latent variables, reflecting the mutual influence between endogenous latent variables (i.e., the effect of rice farmers' low-carbon production intention on the adoption of low-carbon technologies); Γ is the structure coefficient matrix between exogenous and endogenous latent variables, indicating the causal effect of exogenous latent variables X (low-carbon cognition, environmental awareness, value perception, and self-efficacy) on endogenous latent variables Y (low-carbon production intention and adoption of low-carbon technologies); and ζ is the random error vector of the structural equation.

Causal steps approach

Causal steps approach has been widely used to test the effectiveness of mediating variables in the social science field. In this study, causal steps approach was utilized to examine the mediating effect of low-carbon production intention. There are three steps to judge the mediating effect: the first is to test the relationship between key independent variables (i.e., low-carbon cognition, environmental awareness, value perception, and self-efficacy) and dependent variable (i.e., adoption of low-carbon technologies); the second is to examine the effect of key independent variables on the mediating variables; and the third is to analyze the effects of key independent variables and mediating variables on the dependent variable. In addition, we can calculate the marginal effect of the key independent variables to compare the strength of the role of mediating variable.

Hierarchical regression

Hierarchical regression is a multiple regression method used to determine the order of different variables in the regression equation theoretically or according to the actual needs of researchers. In this study, hierarchical regression was utilized to examine the moderating effect of situational variables (i.e., production implementation cost and socio-environmental factor). Specifically, explanatory variables, moderating variables, and interaction terms were successively introduced into the regression model. A comparison of the three models' square sum of partial regression was conducted to determine whether moderating variables and interaction terms significantly affect the dependent variables. Moreover, a moderating effect was observed when the moderating variable and interaction term significantly affected the dependent variables.

Results

Descriptive analysis of sample characteristics

The rice farmers' socio-demographic and farm characteristics are shown in **Table 2**. The respondents were predominantly male (70.11%) and aged from 51 to 60 (39.77%). Most respondents (37.43%) had junior high school education background (with 7∼9 years of education). Besides farming, 29.44% of farmers held part-time jobs. Agriculture represented a long-term occupation for 31–40 years for 34.20% of farmers. 20.38% of farmers indicated that most household earnings came from agricultural production. Overall, the sample distribution of the socio-demographic and farm characteristics were in line with the actual situation, which means the sample was representative of the information of rice farmers in Hubei province.

Low-carbon production status

According to the survey results (see **Table 3**), straw returning was the most adopted technology, with 84.74% of the rice farmers (n = 944) implementing this technology. Moreover, the average cognition level of straw returning was significantly higher than other low-carbon agricultural technologies, substantiating that straw burning prohibition and comprehensive utilization in Hubei province achieved remarkable achievements. Besides, 33.66% of rice farmers (n = 375) sprayed abamectin-containing biological pesticide, and 30.79% (n = 343) adopted intermittent irrigation. However, only 17.68% (n = 197) of farmers adopted the soil testing formula fertilizer.

Reliability and validity testing

SPSS 22.0 and AMOS 22.0 were used to test the reliability and validity of the questionnaire measurement scale (see **Table 4**). The overall Cronbach's α coefficients of the latent variables (i.e., environmental awareness, value perception, self-efficacy, low-carbon production intention, and adoption of low-carbon technologies) were superior to 0.6, suggesting good consistency and reliability of the scale. Although the overall Cronbach's α coefficient of low-carbon cognition was 0.592, it is acceptable for social sciences research (Peterson, 1994). According to the validity analysis, the Kaiser-Meyer-Olkin (KMO) value of all latent variables exceeded 0.6, and Bartlett's sphericity tests were significant at the 1% statistical level, indicating that the scale has good construct validity. Besides, the measured items were suitable for confirmatory factor analysis (CFA).

CFA was used to test the convergent validity of the scale (see **Table 4**). The results showed that the standardized factor loadings of most observational and latent variables exceeded 0.5. Although some observational variables' standardized factor loadings were slightly smaller (between 0.4 and 0.5), they were deemed acceptable (Ford et al., 1986). Additionally, all standardized factor loadings were significant at the 1% statistical level, showing that the scale has good convergent

TABLE 2 Basic characteristics of the surveyed rice farmers.

Variable	Item	Frequency	Percentage	Variable	Item	Frequency	Percentage
Gender	Male	781	70.11	Part time job	Yes	328	29.44
	Female	333	29.89		No	786	70.56
Age	≤40	57	5.12	Educational level (years)	0∼3	192	17.24
	41∼50	287	25.76		4∼6	334	29.98
	51∼60	443	39.77		7∼9	417	37.43
	61∼70	278	24.96		10∼12	153	13.73
	≥71	49	4.40		≥13	18	1.62
Farming experience (years)	≤20	138	12.39	Agricultural income proportion	≤20%	316	28.36
	21∼30	263	23.61		21∼40%	253	22.71
	31∼40	381	34.20		41∼60%	175	15.71
	41∼50	254	22.80		61∼80%	143	12.84
	≥51	78	7.00		≥81%	227	20.38

TABLE 3 Rice farmers' cognition level and adoption of low-carbon agricultural technologies.

Low-carbon agricultural technology	Cognition level from 1 to 5		Status of adoption	
	Sample	Average	Frequency	Percentage
Soil testing formula fertilizer	1,114	2.45	197	17.68%
Biological pesticide	1,114	2.77	375	33.66%
Intermittent irrigation	1,114	2.67	343	30.79%
Straw returning	1,114	3.19	944	84.74%

validity. Meanwhile, each latent variable's composite reliability (CR) was calculated to judge the internal quality and a CR value of a latent variable greater than 0.6 suggested good reliability of the measurement model and high consistency of the factor constructs. As shown in Table 4, the CR values of latent variables were not less than 0.6, demonstrating that the model has good internal quality. Besides, correlations were compared with the square root of AVE values. Table 5 presents the descriptive statistics of the key variables, including the square root of AVE values, means, standard deviations, and correlation coefficients. Since all correlations were smaller than the respective square root of AVE values, the discriminant validity was supported (Fornell and Cha, 1994; Hair et al., 2014). Overall, these results substantiate the reliability and validity of the measurement model.

Model fitting

To solve the issue of Chi-square value (χ^2) expansion driven by large samples, the ratio between Chi-square to the degree of freedom (χ^2/df) was selected as an indicator of fitness (Hair et al., 2010). The results of the goodness of fit test were as follows: N (sample) = 1,114, χ^2/df = 2.351 (<3), GFI = 0.969 (>0.90), AGFI = 0.953 (>0.90), CFI = 0.969 (>0.90), NFI = 0.947 (>0.90), IFI = 0.969 (>0.90), TLI = 0.957 (>0.90), RMSEA = 0.035 (<0.08), CN (0.01) = 609 (>200). The results suggested a good consistency between the theoretical model and the practical data. After deleting insignificant paths between latent variables according to the modification indices, the standardized path coefficient are shown in Figure 3 and Table 6.

The estimation results showed that rice farmers' low-carbon cognition significantly affected their value perception and self-efficacy, with standardized path coefficients of 0.308 and 0.257, respectively. Rice farmers' environmental awareness was positively correlated with their value perception, self-efficacy, and adoption of low-carbon technologies, with standardized path coefficients of 0.311, 0.216, and 0.079, respectively. Moreover, the standardized path coefficients of rice farmers' value perception on their self-efficacy, low-carbon production intention, and the adoption of low-carbon technologies were 0.225, 0.489, and 0.212, respectively. Furthermore, rice farmers' self-efficacy was positively correlated with low-carbon production intention and adopting low-carbon technologies, with path coefficients of 0.192 and 0.575, respectively. Finally, the standardized path coefficient of rice farmers' low-carbon production intention on their adoption of low-carbon technologies was 0.088. Overall, the main effects of the variables in the theoretical model were validated. Additionally, the mediating and moderating effects were further verified by causal steps approach and hierarchical regression.

TABLE 4 Results of the variable reliability and validity analysis.

Variable	No.	Standardized factor loading	Cronbach's α	KMO value	Bartlett's sphericity test		Composite reliability (CR)
					χ^2	p	
Low-carbon cognition (LC)	A1	0.413	0.592	0.612	340.287	0.000	0.600
	A2	0.758					
	A3	0.532					
Environmental awareness (EA)	B1	0.531	0.741	0.626	855.889	0.000	0.759
	B2	0.880					
	B3	0.714					
Value perception (VP)	C1	0.586	0.765	0.777	1063.914	0.000	0.775
	C2	0.658					
	C3	0.778					
	C4	0.694					
Self-efficacy (SE)	D1	0.713	0.766	0.674	901.415	0.000	0.718
	D2	0.659					
	D3	0.661					
Low-carbon production intention (LPI)	Y1	0.852	0.709	0.751	770.877	0.000	0.744
	Y2	0.476					
	Y3	0.459					
	Y4	0.767					
Adoption of low-carbon technologies (ALT)	Z1	0.443	0.652	0.707	588.303	0.000	0.660
	Z2	0.525					
	Z3	0.614					
	Z4	0.695					

Mediating effect

To assess the mediating effect of low-carbon production intention (see Table 7), SPSS 22.0 was employed to centralize the observational variables corresponding to the six latent variables (i.e., low-carbon cognition, environmental awareness, value perception, self-efficacy, low-carbon production intention, and adoption of low-carbon technologies). Then, the mediating effect was analyzed with the mean values of each latent variable by causal steps approach. The results showed that rice farmers' low-carbon cognition affected their adoption of low-carbon technologies through low-carbon production intention; that is, low-carbon cognition indirectly affected the adoption of low-carbon technologies. The ratio of the mediating effect to the total effect was 23.05%, which explained 24.70% of the variance in the dependent variable. Furthermore, other latent variables, namely environmental awareness, value perception, and self-efficacy, affected the adoption of low-carbon technologies through the partial mediating effects of low-carbon production intention; and the mediating effects of low-carbon production intention accounted for 18.16%, 18.56%, and 8.77%, and explained 22.36%, 12.65%, and 14.14% of the variance in the dependent variable, respectively.

Moderating effect

According to the research design, there were two types of moderating variables, namely production implementation cost (i.e., traditional farming habit and risk tolerance) and the socio-environmental factor (i.e., small farmer cultural background, government promotion, and group effect). As previously described by Aiken et al. (1991), Cohen et al. (2003), and Hayes (2013), to make the coefficients of the regression equation more explanatory, the first step in the moderating effect test is to centralize the observational variables corresponding to the seven latent variables (i.e., low-carbon cognition, environmental awareness, value perception, self-efficacy, low-carbon production intention, production implementation cost, and socio-environmental factor). Then, the moderating effect was analyzed with the mean values of the centralized observational variables included in the above seven latent variables. Given that there is no need to centralize the dependent variable during moderation analysis, the mean value of the observational variables corresponding to rice farmers' adoption of low-carbon technologies was introduced directly into the hierarchical regression model. Finally, independent variables, moderating variables, and interaction terms were introduced successively for hierarchical regression (see Table 8).

TABLE 5 Descriptive statistics of key variables.

Variable	LC	EA	VP	SE	LPI	ALT
LC	**0.586**					
EA	0.324***	**0.722**				
VP	0.383***	0.369***	**0.683**			
SE	0.274***	0.313***	0.314***	**0.678**		
LPI	0.216***	0.246***	0.474***	0.297***	**0.662**	
ALT	0.238***	0.313***	0.378***	0.518***	0.294***	**0.577**
Mean	2.405	3.390	3.659	3.132	3.797	2.392
Standard deviation	0.795	1.106	0.842	1.098	0.693	0.898

This table presents the descriptive statistics of the key variables, including the square root of AVE values, means, standard deviations, and correlation coefficients (*** represents significant at 1%). Square roots of AVE values are shown in bold on matrix diagonal.

TABLE 6 Path coefficients of the structural equation modeling.

Path	Standard path coefficient	SE	CR	*P*
Low-carbon cognition → Value perception	0.308	0.110	5.890	***
Low-carbon cognition → Self-efficacy	0.257	0.118	5.034	***
Low-carbon cognition → Low-carbon production intention	–	–	–	–
Low-carbon cognition → Adoption of low-carbon technologies	–	–	–	–
Environmental awareness → Value perception	0.311	0.048	7.595	***
Environmental awareness → Self-efficacy	0.216	0.058	4.780	***
Environmental awareness → Low-carbon production intention	–	–	–	–
Environmental awareness → Adoption of low-carbon technologies	0.079	0.049	1.983	**
Value perception → Self-efficacy	0.225	0.051	4.814	***
Value perception → Low-carbon production intention	0.489	0.046	11.706	***
Value perception → Adoption of low-carbon technologies	0.212	0.051	4.344	***
Self-efficacy → Low-carbon production intention	0.192	0.038	5.155	***
Self-efficacy → Adoption of low-carbon technologies	0.575	0.054	10.179	***
Low-carbon production intention → Adoption of low-carbon technologies	0.088	0.038	2.176	**

** and *** represent significant at 5% and 1%, respectively.

TABLE 7 Mediating effect of the low-carbon production intention.

IV	M	DV	IV→DV	IV→M	IV+M→DV		Mediation type
					IV	M	
LC	LPI	ALT	0.238***	0.216***	0.183***	0.254***	Partial mediation
EA	LPI	ALT	0.313***	0.246***	0.256***	0.231***	Partial mediation
VP	LPI	ALT	0.378***	0.474***	0.308***	0.148***	Partial mediation
SE	LPI	ALT	0.518***	0.297***	0.472***	0.153***	Partial mediation

IV, M, and DV are independent variables, mediating variables, and dependent variables, respectively. *** represents significant at 1%.

As shown in Table 8, the production implementation cost negatively moderated the effect of self-efficacy on farmers' adoption of low-carbon technologies. Besides, socio-environmental factor positively moderated the effects of environmental awareness and self-efficacy on farmers' adoption of low-carbon technologies but negatively moderated the effect of low-carbon production intention. Figure 4 depicts the moderating effects of production implementation cost and socio-environmental factor on the path of rice farmers' adoption of low-carbon technologies. The essence of moderating effect is considering how it affects the relationship between independent and dependent variables when the moderating variable is at a high and a low level, respectively. As shown in Figure 4, if the effect value (i.e., the slope) of the high group (i.e., when the moderating variable is at the high level) was greater than the effect value of the low group (i.e., when the moderating variable is at the low level), it exerted an enhancement effect on the pathway of "independent variable → dependent variable," and vice versa.

As seen in Figure 4A, a robust positive moderating effect was observed between self-efficacy and adoption of low-carbon technologies for rice farmers with low production implementation cost, suggesting that improving their self-efficacy perception contributed to promoting the adoption of low-carbon technologies. However, for rice farmers with high production implementation cost, self-efficacy slightly affected

TABLE 8 Moderating effects of production implementation cost and socio-environmental factor.

Variable	[M_1] = Production implementation cost			[M_2] = Socio-environmental factor		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
(constant)	2.392***	2.393***	2.395***	2.392***	2.392***	2.374***
Low-carbon cognition	0.011	−0.022	−0.025	0.011	−0.019	−0.022
Environmental awareness	0.101***	0.088***	0.084***	0.101***	0.100***	0.089***
Value perception	0.180***	0.161***	0.161***	0.180***	0.180***	0.189***
Self-efficacy	0.409***	0.428***	0.434***	0.409***	0.425***	0.433***
Low-carbon production intention	0.060**	0.026	0.035	0.060**	0.034	0.035
Moderating variables [M_i]		−0.141***	−0.133***		−0.098***	−0.103***
Low-carbon cognition × [M_i]			0.002			−0.005
Environmental awareness × [M_i]			0.021			0.068**
Value perception × [M_i]			0.047			−0.044
Self-efficacy × [M_i]			−0.060**			0.058**
Low-carbon production intention × [M_i]			−0.040			−0.073**
Adjusted R^2	0.328	0.344	0.345	0.328	0.336	0.343
Variation of R^2	0.331	0.016	0.004	0.331	0.008	0.010

** and *** represent significant at 5% and 1%, respectively.

their adoption of low-carbon technologies. It could be seen that the production implementation cost had an interferential effect on the pathway of "self-efficacy → adoption of low-carbon technologies." Thus, reducing the cost or risk of adopting low-carbon agricultural technologies would contribute to the positive transformation from farmers' self-efficacy perception to actual adoption behavior.

We found that environmental awareness strongly affected the adoption of low-carbon technologies for rice farmers with high socio-environmental factor, suggesting that improving their environmental awareness can effectively encourage them to engage in low-carbon production (see **Figure 4B**). Besides, the effect was dramatically diminished for rice farmers with low socio-environmental factor. It could be seen that the socio-environmental factor had an enhancement effect on the pathway of "environmental awareness → adoption of low-carbon technologies," suggesting that green and low-carbon social environment could induce better environmental awareness of rice farmers, and they were more likely to be engaged in low-carbon production. Accordingly, the socio-environmental factor played a vital catalytic role in farmers' adoption of low-carbon agricultural technologies.

Compared to rice farmers with low socio-environmental factor, the positive effect of self-efficacy on adopting low-carbon technologies was more potent for rice farmers with high socio-environmental factor (see **Figure 4C**). Accordingly, the socio-environmental factor reinforced the effect of self-efficacy on farmers' adoption of low-carbon technologies. It could be seen that socio-environmental factors enhanced the pathway of "self-efficacy → adoption of low-carbon technologies." In other words, a positive social environment for low-carbon agriculture could strengthen rice farmers' self-efficacy, making them more likely to adopt low-carbon technologies. Accordingly, if a social environment advocating low-carbon agricultural production was established via the local government, it would contribute to the positive transformation from farmers' self-efficacy to actual adoption behavior.

For rice farmers with low socio-environmental factor, low-carbon production intention positively influenced their adoption of low-carbon technologies (see **Figure 4D**). Consequently, enhancing those farmers' low-carbon production intention could effectively promote their low-carbon production participation, compared with rice farmers with high socio-environmental factor. Importantly, it can be seen that the socio-environmental factor exerted an interferential effect on the pathway of "low-carbon production intention → adoption of low-carbon technologies," accounting for the "high intention—low behavior" phenomenon. In fact, for rice farmers lacking low-carbon agricultural material knowledge and professional equipment for field management, their adoption of low-carbon technologies remained challenging even when they had subjective intents (Wang et al., 2018). This finding applied to farmers' first exposure to these new agricultural materials and production equipment, such as biological pesticide, soil testing formula fertilizer, intermittent irrigation facility, etc.

Discussion

Theoretical contributions

In the present study, the adoption rates of soil testing formula fertilizer, biological pesticide, intermittent irrigation, and straw returning by sample rice farmers were 17.68%,

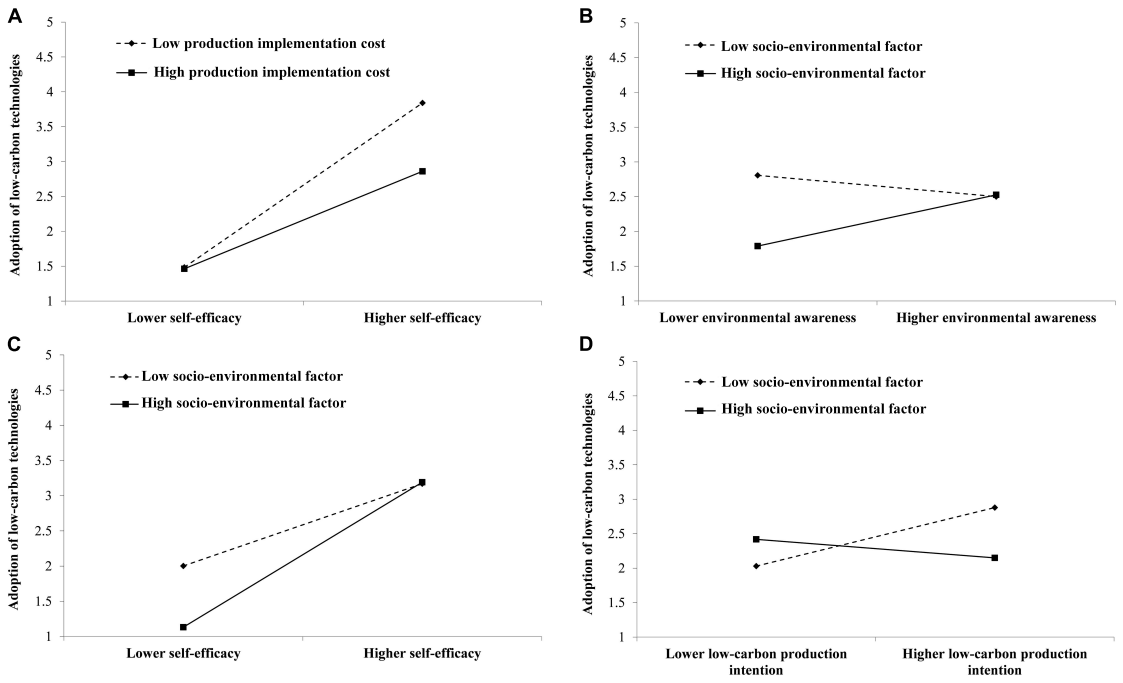

FIGURE 4
Moderating effects of production implementation cost and socio-environmental factor. **(A)** Production implementation cost moderates the effect of self-efficacy on the adoption of low-carbon technologies. **(B)** Socio-environmental factor moderates the effect of environmental awareness on the adoption of low-carbon technologies. **(C)** Socio-environmental factor moderates the effect of self-efficacy on the adoption of low-carbon technologies. **(D)** Socio-environmental factor moderates the effect of low-carbon production intention on the adoption of low-carbon technologies.

33.66%, 30.79%, and 84.74%, respectively. This finding suggested that the straw burning ban and comprehensive utilization management in Hubei province achieved remarkable achievements, but the adoption rates of other low-carbon agricultural technologies were dismal. Over the years, much emphasis has been placed on the effects of demographic (Jain and Rekha, 2017), economic (Liu et al., 2019), and environmental factors (Zhang et al., 2019) on farmers' adoption of low-carbon technologies. Overwhelming evidence substantiates that psychological factors can change farmers' adopting behavior (Jiang et al., 2018; Yu et al., 2018), and a comprehensive analysis framework based on farmers' production practices has not been established to date. To fill this gap, our study comprehensively assessed farmers' adoption of low-carbon technologies from four aspects, namely soil testing formula fertilizer, biological pesticide, intermittent irrigation, and straw returning, and constructed a theoretical model of rice farmers' adoption of low-carbon technologies. Furthermore, based on questionnaires from Chinese rice farmers (n = 1,114), the theoretical model was empirically tested by SEM.

Importantly, we found that when farmers lacked basic cognition of climate change, low-carbon technologies, and environmental awareness, they could not perceive the value of adopting low-carbon technologies, further hindering intention formation and the actual adoption behavior. Compared to the literature (Jiang et al., 2018; Yu et al., 2018), our theoretical model based on rice farmers' low-carbon production practice enriched the multidimensional connotation of farmers' low-carbon production attitude and behavioral efficacy, and comprehensively explained the psychological factors driving the adoption of low-carbon technologies.

Meanwhile, growing evidence suggests that unique abilities and circumstances often limit the transformation from individual intention to actual behavior, described as the phenomenon of "high intention—low behavior" (Vande Velde et al., 2018). Unlike these previous studies (Sharifzadeh et al., 2017; Hyland et al., 2018), this paper confirms and extends this finding from the practical level. Rice farmers' environmental awareness, self-efficacy, and low-carbon production intention will be moderated and restricted by situational factors (i.e., production implementation cost and socio-environmental factor). The high costs or risks of adopting low-carbon agricultural technologies can inevitably impede the transformation of rice farmers' self-efficacy perception into actual adoption behavior. Creating a green and low-carbon social environment can enhance the effects of environmental awareness and self-efficacy on rice farmers' adoption of low-carbon technologies. Subsequently, rice farmers were more

likely to engage in low-carbon production. However, it should be borne in mind that socio-environmental factor has a significant negative moderating effect on the pathway of "low-carbon production intention → adoption of low-carbon technologies." It indicates that the effect of low-carbon production intention on the adoption of low-carbon technologies is less substantial due to farmers' lack of knowledge on low-carbon production (about biological pesticide and soil testing formula fertilizer) or the external resources conditions (of technical guidance, intermittent irrigation facilities, etc.) for field management although the social environment may help improve the subjective intents of farmers.

Policy implications

This research provides four critical connotations for the policymakers of developing countries that aim to popularize low-carbon agriculture to protect the global climate. First of all, since the low-carbon production attitude of farmers has a positive effect on the adoption of low-carbon technologies mediated by the effect of low-carbon production intention, improving farmers' attitude and intention can effectively promote low-carbon agricultural technologies. Low-carbon agricultural knowledge and technical training are key to improving farmers' attitude toward low-carbon production and increasing low-carbon production intention. Governments of developing countries can improve the popularization of low-carbon agricultural knowledge with the help of new media platforms. Importantly, intensive, comprehensive, and sustainable low-carbon agricultural knowledge propaganda is a reasonable way to activate and arouse farmers' intention toward low-carbon production from the psychological level.

Secondly, besides the direct positive effect, farmers' behavioral efficiency perception also positively affects the adoption of low-carbon technologies mediated by low-carbon production intention. Therefore, improving farmers' behavioral efficiency perception is necessary for promoting low-carbon agriculture. Specifically, agricultural research institutes can refine low-carbon technologies such as intermittent irrigation and straw returning and provide low-carbon agricultural production guidance to enhance farmers' confidence and perception of efficiency in implementing low-carbon production.

Moreover, given that the implementation costs of low-carbon agriculture hinder farmers from adopting low-carbon agricultural technologies, government subsidies may be a solution. Indeed, in most developing countries, agricultural income is the primary source for farmers, and agricultural production costs are critical to their livelihoods. Accordingly, improving the subsidies for low-carbon agriculture and reducing the low-carbon production costs of farmers are paramount approaches to promoting low-carbon agriculture. Furthermore, ecological compensation should be incorporated into the agricultural subsidies, which is beneficial to reduce the direct and hidden costs of low-carbon production for farmers and stimulate their enthusiasm for participating in low-carbon production.

Last but not least, the production activities of farmers occur in a specific social environment. Therefore, the need for establishing a green and low-carbon social environment should be emphasized. A green and low-carbon social environment will induce environmental awareness and higher self-efficacy in farmers, who are more likely to engage in low-carbon production. However, socio-environmental factor negatively moderates the effect of farmers' low-carbon production intention on the adoption of low-carbon technologies, which leads to the phenomenon of "high intention—low behavior" of farmers in low-carbon production. More precisely, although the low-carbon production social environment may help improve the subjective intention of farmers, the effect of low-carbon production intention on the adoption of low-carbon technologies will be less significant if farmers live in an environment bereft of knowledge of low-carbon agricultural materials and professional field management equipment. Consequently, low-carbon agricultural information promotion and low-carbon agricultural technologies training are crucial for individual farmers and critical to creating a green and low-carbon social environment, which fosters farmers to carry out low-carbon production. At the same time, the infrastructure, machinery, and equipment required for low-carbon agriculture are heavy financial burdens for farmers. The low-carbon agricultural production loan policies and agricultural materials subsidies are practical methods to reduce these costs.

Limitations and further research

The empirical results reported herein should be considered in light of some limitations. As shown above, rice cultivation is the main occupation of most farmers, and rice yield and economic returns are of great importance to them. Whether farmers finally adopt low-carbon agricultural technologies depends on psychological factors (i.e., low-carbon production attitude, behavioral efficiency perception, and low-carbon production intention) and the actual financial benefits. In addition, the financial benefits of adopting those technologies can affect farmers' psychological perceptions of low-carbon agriculture. Given that the returns on investment of farmers' adoption behavior were not studied in this paper, we could not analyze how the economic benefits of adopting low-carbon agricultural technologies affect the psychological changes of farmers.

Based on the above analysis, we believe that the psychology related to farmers' adoption behavior of low-carbon agricultural technologies is a topic worth exploring in the future. Moreover, experimental data could be used to validate the theoretical model proposed in this paper. Finally, the cost and benefit data of low-carbon production can be accurately collected in field experiments to further study the mechanism underlying the influence of economic factors affecting psychological cognition and the actual behavior of farmers.

Conclusion

The previous literature on farmers' adoption of low-carbon technologies has highlighted demographic, economic, and environmental factors (Jain and Rekha, 2017; Liu et al., 2019; Zhang et al., 2019), while farmers' psychology has been largely underexplored. Our results substantiated that farmers' low-carbon production attitude and behavioral efficiency perception directly and positively affected the adoption of low-carbon agricultural technologies and indirectly affected it via low-carbon production intention. Therefore, more supportive policies are warranted to improve farmers' low-carbon production attitude and behavioral efficiency perception. Moreover, the direct effects of low-carbon production attitude, behavioral efficiency perception, and low-carbon production intention on farmers' adoption of low-carbon agricultural technologies were moderated by production implementation cost and socio-environmental factor. In this respect, socio-environmental factor yielded more significant moderating effect. This observation corroborates that advocating a social environment for low-carbon agricultural production is essential for improving farmers' adoption behavior which could be harnessed to develop new policies to foster farmers' adoption of low-carbon technologies.

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.

Ethics statement

The studies involving human participants were reviewed and approved by the National Natural Science Foundation of China (Project No. 72003051) and the Ministry of Education of Humanities and Social Science of China (Project No. 19YJC790048). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

LJ conceived and designed the study and performed the empirical analysis of survey data. HQH contributed significantly to manuscript preparation. SH, HYH, and YL was put forward valuable idea and participated in wrote the manuscript. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

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Factors affecting the adoption of green prevention and control techniques by family farms: Evidence from Henan province of China

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Encouraging farmers to adopt green prevention and control techniques (GCTs) is conducive to ensuring the quality and safety of agricultural products, the ecological environment and agricultural production in China. To explore the factors influencing vegetable farmers' adoption of GCTs, this study utilized the "information-motivation-behavior" intervention (IMB) model and ordered logistic model to empirically study the adoption behavior of 653 vegetable farmers in Henan Province, China. Estimation results indicated that the IMB model significantly predicted farmers' adoption of GCTs: 1) From the perspective of adoption decisions, 88.82% of the farmers have adopted GCTs, but the degree of adoption is low. 2) the farmers' adoption of GCTs IMB model specifies that higher levels of GCTs information, motivation, and behavioral skills should result in a greater likelihood of engaging in GCTs adoption behavior. 3) Motivation and behavioral skills are activated through information. 4) Finally, motivation can indirectly affect farmers' GCTs adoption behavior through behavioral skills. The results of this study support the need for the government to promote the use of GCTs for vegetable pest control, as well as advance integrated prevention and control in the agricultural industry.

KEYWORDS

green prevention and control techniques, adoption behavior, IMB model, vegetable farmers, ordered probit model

1. Introduction

Currently, irregularities such as increased chemical pesticide application, accelerated application frequency and shorter intervals are common among Chinese farmers, and excessive chemical pesticide application has caused increased agricultural surface pollution and agroecosystem degradation and it poses a serious

threat to the quality and safety of water bodies and soil (Lou et al., 2021; Yu et al., 2021a). To reduce and control the usage of chemical pesticides, and provide ecological and environmental safety, thereby promoting the sustainable development of agriculture, China's government is committed to promoting the Chinese practice of green prevention and control techniques (GCTs). GCTs is the Chinese concept of integrated pest management (IPM) and prioritizes adopting resource-saving and environmentally friendly technical measures such as ecological regulation, biological control, physical control, and scientific pesticide use. Furthermore, it helps reduce crop losses, increase yields, and improve the net income and welfare of farmers (Wang et al., 2015; Gao et al., 2017). However, compared to traditional production technology methods, GCTs require higher labor inputs and more stringent operational requirements. Farmers, as "rational economic people," will inevitably consider factors such as costs, benefits, and risks, which lead to differences in the adoption of GCTs by farmers and make it difficult to achieve large-area diffusion of green control technologies (Gao et al., 2017; Gao and Niu, 2019). At present, the use of GCTs in China remains mainly experimental and implemented at a small scale, and has become one of the "bottlenecks" limiting the sustainable development of Chinese agriculture (Yu et al., 2020a, 2021a). Demand from farmers, who constitute the micro decision-making body of agricultural production and operation, would be the basis for the successful application of GCTs. Therefore, we explored the influencing factors of Chinese farmers' adoption of GCTs.

Scholars have conducted extensive and in-depth studies on the factors that influence the adoption behavior of GCTs by farmers. It is generally believed that GCTs adoption is related to farmers' individual characteristics (Abebaw and Haile, 2013; Murage et al., 2015; Kolleh, 2016; Luo et al., 2022), resource endowment characteristics (Allahyari et al., 2016; Gao et al., 2019a; Luo et al., 2019; Niu et al., 2022), and cognitive characteristics (Kabir et al., 2017; Gao et al., 2019b). Moreover, GCTs adoption is also related to external factors such as government regulation (Gao et al., 2019c), technology integration (Benelli et al., 2017; Fatima et al., 2022), and technical training (Geng et al., 2017). By combing the literature, the current domestic and international studies on the factors influencing farmers' GCTs adoption behavior mainly show the following characteristics. First, the studies are mostly about farmers' own resource endowment (Xiong and He, 2020), social networks (Gao et al., 2019a), economic incentives (Geng et al., 2017) and technical characteristics (Gao et al., 2020; Liu et al., 2022) effects on farmers' GCTs adoption behavior, and there is a lack of research on farmers' psychological motivation. Second, the research objects are mostly about whether farmers adopt GCTs, ignoring the gradual process of GCTs adoption and the degree of adoption by farmers (Lin et al., 2021). Third, the research subjects are mostly food crop farmers, ignoring the research on farmers in other farming industries (Korir et al., 2015; Allahyari et al., 2016; Geng et al., 2017). Agricultural non-point source pollution is hidden, scattered, and difficult to find. On the premise of not changing the individual's awareness and concept of green prevention and control, there are no prescribed best practices for implementing effective behavioral interventions targeting constraining farmers to adopt GCTs. Psychologically-based interventions may be useful in explaining and ultimately promoting the adoption behavior of GCTs by farmers. As such, the current study incorporates the information-motivation-behavior intervention (IMB) model into the theoretical analysis framework to explore the influence of psychological factors on farmers' adoption of GCTs.

The IMB model was first designed by Fisher and Fisher (1992), who took behavioral intervention as the starting point for determining behavioral change and divided the factors affecting individual behavioral change into three parts: information, motivation, and behavioral skill. Among them, information refers to the knowledge related to individual behavior transmission that can lead individuals to think and transform their behavior. Motivation refers to the individual's attitude (personal motivation) and subjective norms (social motivation), including the individual's expectations of the costs and benefits of adopting the behavior, as well as social norms. Behavioral skills refer to the skills that facilitate the effective implementation of behavior, which provide a guaranteed basis for behavioral safety (Fisher et al., 2014). The above three can act as mutually independent entities to influence individual behavior directly, or they can interact with each other to influence individual behavior indirectly. The IMB model further distinguishes itself from other behavior change models (e.g., the theory of reasoned action, Fishbein and Ajzen, 1975; transtheoretical model, Prochaska et al., 1992) by outlining a three-step approach to designing interventions that are tailored to a specific population: elicitation, design and implementation, and evaluation. Thus, the IMB model provides a theoretical understanding of behavior change and a guide for designing theory-informed interventions. The IMB model has been used successfully in multiple health domains (Fisher et al., 2014) and is increasingly used in other fields, including recycling behavior (Seacat and Northrup, 2010), farmers' willingness to adopt agricultural technology (Zhang et al., 2020), and water conservation behavior (Ehret et al., 2021). Based on this, this paper attempts to incorporate the "information-motivation-behavior skill" behavioral intervention model into the theoretical framework to analyze farmers' GCTs adoption behavior and provide new ideas for exploring effective paths to enhance farmers' GCTs adoption behavior.

2. Theoretical framework and research hypothesis

2.1. Information and farmers' GCTs adoption behavior

According to the IMB model, information relevant to performing the desired behavior is a prerequisite to the correct and consistent performance of that behavior (Fisher et al., 2006). Within the domain of green agricultural production, researchers have demonstrated the important role that information has in promoting and maintaining farmers' green production behavior (Korir et al., 2015 and Zhang et al., 2020). Persuasion theory believes that by disseminating a certain aspect of information, individuals will deepen their understanding of this aspect of knowledge, and when they have enough of this information, they will often persuade themselves to actively participate, and then affect the individual's related willingness and decision-making (Lou et al., 2021; Luo et al., 2022). In the incomplete information context, information intervention in the information channel mainly shapes farmers' behavior through the paths of sharing information resources, enhancing risk prevention and control, and reducing transaction costs, and farmers with more information channels also receive stronger information intervention and have a greater likelihood of adopting green prevention and control technology behavior (Zhang et al., 2020; Yu et al., 2021a; Shi and Zhang, 2022). In addition, farmers also have information needs in the process of green prevention and control technology adoption decisions, and whether the information needs of farmers can be met mainly depends on whether farmers have rich information access channels (Yan and Liu, 2022). Farmers with rich information channels can obtain more positive information in the process of information transfer and can give full play to the value of such information, and the advantages of farmers' adoption of green prevention and control technology will be more obvious (Wang et al., 2021a; Li et al., 2022). Based on this, the following hypothesis is proposed in the paper.

> *H1*. Information acquisition has a significant positive effect on farmers' GCTs adoption behavior.

2.2. Motivation and farmers' GCTs adoption behavior

The IMB model posits that behavioral change is more likely when individuals are motivated (Fisher et al., 2014). We define motivation as the driving force that motivates individual behavior, and gaining more profit, appreciation, and avoiding punishment are the most fundamental motives that promote farmers' green prevention and control technology behavior. According to the IMB model, motivation exists on two levels: individual and social with both forms of motivation being influenced by differing sources (Seacat and Northrup, 2010). On the personal level, a high level of motivation and positive attitude toward performing a behavior is based upon the belief that one can successfully engage in the desired behavior and that the outcome of engaging in this behavior will be beneficial to the self. Further, individuals need to believe that the costs associated with performing the desired behavior outweigh the costs of engaging in that behavior (Ehret et al., 2021). At the social level, motivation is based on individuals' perceptions of social support (e.g., government or cooperatives) for engaging in the desired behavior (Gao et al., 2019a). With regard to green agricultural production behavior, it is well-recognized that personal attitudes and social support are critical to engaging in pro-environmental behavior (Gao et al., 2017). In the process of agricultural production, farmers, as "rational economic people," will always make the best production decision. On the one hand, farmers have the most fundamental production motivation to pursue maximum economic benefits, thus, the higher the market value recognition degree of green agricultural products produced by farmers, the greater the possibility of farmers adopting green prevention and control technology (Geng et al., 2017). On the other hand, consistent with the IMB Model, the arrangement of relevant government incentives and restraint policies will guide and standardize farmers' production behavior (Lin et al., 2021). Agricultural technology subsidies as a form of financial compensation are the most effective external incentive for behavioral interventions and can promote farmers' active participation in rural public environmental governance (Gao et al., 2019b; Lou et al., 2021). However, to avoid the risk of penalties associated with non-environmental behaviors, farmers will continue to adopt environmentally friendly production technology behaviors (Mao et al., 2021; Hu et al., 2022). Based on this, the following hypothesis is proposed.

> *H2.* Motivation has a significant positive effect on farmers' GCTs adoption behavior.

2.3. Behavioral skills and farmers' GCTs adoption behavior

The final critical prerequisite of engaging in the desired behavior is the possession of the appropriate behavioral skills by individuals, to successfully perform appropriate behaviors (Fisher et al., 2014). Behavioral skills consist of individuals' objective abilities as well as their perceived self-efficacy concerning the performance of appropriate behaviors (Seacat and Northrup, 2010). Green prevention and control technology adoption behavior skill refers to the green prevention and control technology that farmers understand and master (Gao et al., 2019c; Luo et al., 2022). For most farmers, green prevention and control technologies have technical barriers, such as difficulty in operation and high requirements, which are the key reasons that currently

inhibit farmers' adoption of green prevention and control technologies (Shi and Zhang, 2022; Yu et al., 2022). However, participation in agricultural technology training can help farmers effectively master agricultural technology skills, deepen their understanding of agriculture-related technologies and policies, and improve the accessibility of agricultural technologies to farmers, thus breaking down agricultural technology barriers (Gao et al., 2019c; Zhang et al., 2020). At the same time, agricultural technology promotion and training can effectively reduce the use of chemical inputs in agricultural production, improve farmers' knowledge and understanding of agricultural green production technologies in the process of technical guidance, and promote the rationalization of farmers' chemical input behavior (Gao et al., 2017; Niu et al., 2022). Consistent with the IMB model, higher levels of perceived GCTs behavioral skills among individuals should lead to a greater likelihood that these individuals will engage in green prevention and control technology adoption behavior. Based on this, the following hypothesis is proposed.

> *H3.* Behavioral skills have a significant positive effect on farmers' GCTs adoption behavior.

2.4. IMB model and farmers' GCTs adoption behavior

Although information and motivation may have direct effects on behavior when the target action does not require complex skills (Fisher et al., 2014), the IMB model proposes that information and motivation often indirectly influence actions *via* behavioral skills, consistent with the reasoned action model (Fishbein and Ajzen, 1975). That is, higher levels of information and motivation lead individuals to believe they can engage in and/or objectively be able to engage in the target behavior, moving them to acquire the skills necessary to undertake the behavior (Seacat and Northrup, 2010; Ehret et al., 2021). The transmission of intergroup information can make farmers feel the correct social norms and standards, enhance their motivation for behavior change (Zhang et al., 2020; Zhao et al., 2021), and provide new knowledge and techniques that are acceptable to farmers, ultimately creating an atmosphere conducive to their behavior change (Qin and Lv, 2020; Wu and Zhou, 2021; Shi and Zhang, 2022). In addition, by breaking through the barrier of information blockage through multiple channels of positive information, farmers not only help break the technical barrier of high cost and difficulty in mastering but also help reduce their risk perception of adopting new technology behavior (Zhou et al., 2022), improve their perception of economic benefits, and promote positive behavioral motivation, which in turn drives farmers' enthusiasm to adopt ecological farming behavior (Mao et al., 2021; Wang et al., 2021b). Moreover, farmers with higher perceptions of economic benefits and risk preferences are more motivated to engage in agricultural production, are happy to participate in new technology training activities and are more inclined to try new technologies with high returns and risks (Wang et al., 2015; Yu et al., 2020b, 2021b; Hu et al., 2022). Based on this, the following hypotheses are proposed.

> *H4.* Information acquisition has a significant positive effect on farmers' GCTs adoption motivation.
>
> *H5.* Information acquisition can act on farmers' GCTs adoption behavior through motivation mediation.
>
> *H6.* Information acquisition has a significant positive effect on farmers' GCTs behavioral skills.
>
> *H7.* Information acquisition can act on farmers' GCTs adoption behavior through behavioral skills mediation.
>
> *H8.* Motivation has a significant positive effect on farmers' GCTs behavioral skills.
>
> *H9.* Motivation can act on farmers' GCTs adoption behavior through behavioral skills mediation.

In summary, the theoretical framework for examining the applicability of the IMB model in predicting farmers' adoption of GCTs is shown in Figure 1. To test these hypotheses, we carry out a survey that is presented in the next part of this paper.

3. Research design and methodology

3.1. Questionnaire design

We designed a questionnaire related to the behavior of vegetable farmers adopting GCTs by referring to the scale designed by previous studies on the different research objects' behavior of green production technology. Our questionnaire includes five parts.

Part 1 was vegetable farmers' socio-demographic characteristics, production and operation characteristics. *Householder characteristics*. (1) Gender. We code the gender variable such that "male" equals 1 and "female" equals 0. (2) Age. We measure a householder's age as his/her actual age. (3) Degree of education. We use a householder's number of years of education to measure the education variable. (4) Village cadre status. Village cadre members are usually rural elites who have more information about green production conditions and new technologies and are likely to sign long-term written

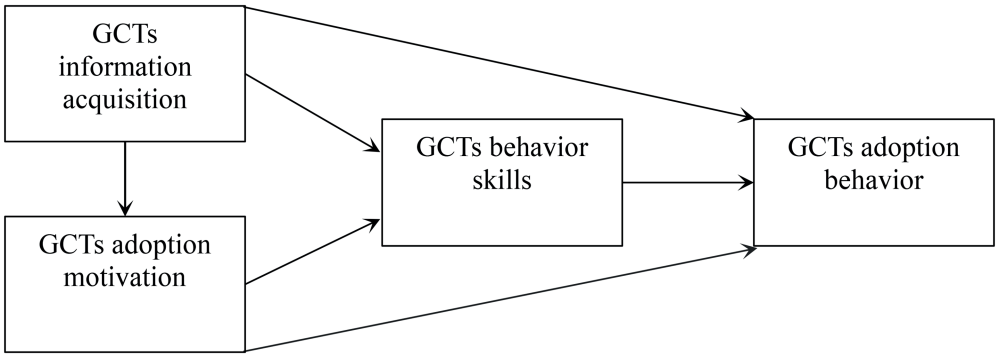

FIGURE 1
The theoretical framework for examining farmers' adoption of GCTs in IMB model.

contracts and adopt new technologies in response to the government's call to lead by example (Jiang et al., 2018; Zeng et al., 2019). We code this variable such that "yes" equals 1 and "no" equals 0. *Production and operation characteristics*. (1) Incentives for green planting. Referring to Shi and Zhang (2022)'s method of dealing with the problem, we code this variable such that "yes" equals 1 and "no" equals 0. (2) Number of laborers. We measure the labor force quantity as the number of household laborers and long-term employees. (3) Degree of participation in agricultural orders. Referring to Shi and Zhang (2022)'s method of dealing with the problem, we measure degree of participation in agricultural orders on a 5-point Likert scale.

Part 2 investigated vegetable farmers' adoption behavior of green prevention and control techniques. Based on the "one control, two reduction and three basic" surface pollution prevention and control objectives proposed by the Ministry of Agriculture in 2020 and taking into account the actual situation in Henan Province, five specific indicators were selected to measure the adoption of GCTs by farmers: pollution-free pesticide application, organic fertilizer application, green fertilizer planting, soil formula fertilizer application and mulch disposal. The farmers who participated in 0 items were never adopted and assigned a value of 1; those who participated in 1–2 items were occasionally adopted and assigned a value of 2; those who participated in 3 items were frequently adopted and assigned a value of 3; those who participated in 4 items were often adopted and assigned a value of 4; and those who participated in 5 items were always adopted and assigned a value of 5. The higher the score is, the higher the degree of adoption of GCTs by farmers.

Part 3 is GCTs information acquisition. Narrow information channels are a serious obstacle to farmers' access to information resources and an important factor affecting the degree of farmers' GCTs adoption behavior (Yang et al., 2020). Therefore, "information access channels: government, cooperative, neighborhood or friends, media" was selected as the measure of information, with the following criteria: 0 means no information channels, 1 means 1 information channel, 2 means 2 information channels, and 3 means 3 information channels, 4 means 4 information channels.

Part 4 is GCTs adoption motivation. The most fundamental motivation of smallholder farmers is to pursue profit maximization, and behavioral costs, rewards and penalties are the key factors affecting smallholder motivation (Shi and Zhang, 2022). Drawing on the following scholars' research (Zhang et al., 2020; Xiong et al., 2021), we selected the following six specific indicators as the measure of motivation: "GCTs adoption behavior is conducive to improving the quality of vegetables," "GCTs adoption behavior is conducive to obtaining green certification," "GCTs adoption behavior is conducive to increasing planting income," "GCTs adoption behavior is beneficial to save production cost," "government subsidies for GCTs promotion services" and "local penalties for agricultural surface source pollution."

Part 5 is GCTs behavior skills. Agricultural technology promotion and training are important ways to enhance farmers' knowledge of agricultural technology. Based on the method of Shi and Zhang (2022) and Ehret et al. (2021), we selected "whether to participate in various types of training such as agricultural land protection technology," "whether to often communicate with agricultural technicians," "whether to often learn green prevention and control technology publicity materials" to measure GCTs behavioral skills.

3.2. Data sources

3.2.1. Introduction to the study area

The data for this study were obtained from field research conducted by the research team from April to October 2021 on vegetable farmers in Henan Province (as shown in Figure 2). The sample selection area is based on the following considerations. On the one hand, Henan Province, a big vegetable province in China, has an average vegetable planting area of about 1.88 million hm^2 every year, and its total output ranks among the top in China. Henan Province is rich in vegetable varieties, with more than 150 kinds of vegetables in more than 10 categories. It is an important

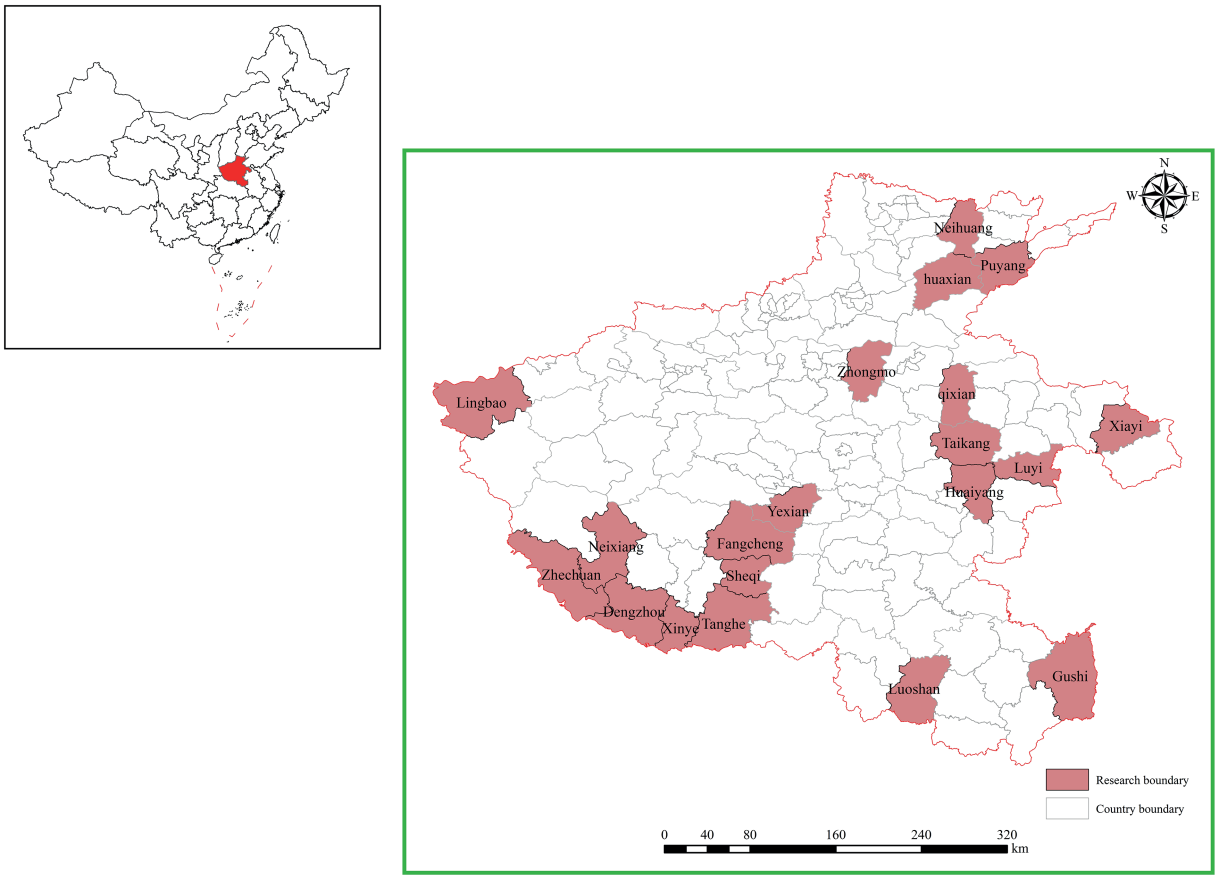

FIGURE 2
The position of Henan province in China and study area.

producing area of high-quality Chinese cabbage, tomato, radish, pepper, ginger, garlic and other crops, providing a large number of vegetables for domestic and foreign regions every year. Therefore, taking Henan Province as the investigation area is helpful to obtain a comprehensive and sufficient sample of vegetable farmers. On the other hand, due to the unsustainable agricultural production modes such as intensive use of chemicals, over-utilization of cultivated land and over-exploitation of groundwater in some areas in the early stage, the soil organic matter in Henan Province is only 19.2 g/kg in 2020, which is lower than the national average level of 24.9 g/kg of cultivated land. As the "hardest hit area" where pesticides and fertilizers are intensively used, the soil quality of vegetable fields is even less optimistic. Facing the urgent situation of agricultural green production transformation. In recent years, Henan provincial government has adhered to the plant protection policy of "putting prevention first and comprehensive prevention and control," mainly through five core technical means: ecological regulation, agricultural control, physical and chemical inducement control, biological control and scientific drug use, and strive to achieve a green prevention and control coverage rate of 55% by 2025. Therefore, taking vegetable farmers in Henan Province as the research object has good representativeness, data support and practical significance.

3.2.2. Sample selection and data collection

The sample is vegetable farmers in Henan Province, China. The survey was conducted in two stages. The first stage was the pre-investigation stage. In April 2021, 30 family farms in Henan Province were randomly selected for household interviews to pre-test the questionnaire to delete unclear questions and add additional questions. A mixed team of five enumerators, majoring in agricultural economics or ecological psychology, was chosen to collect the data. To improve data accuracy, all the enumerators attended a three-day training workshop. The clarity of the questionnaire was improved after this stage. The second stage was the formal survey, which was conducted from May to October 2021. A stratified random sampling method was used to gather data. First, all the selected counties in Henan province were sorted according to regional GDP and divided into five categories: very high, relatively high, medium, relatively low, and very low. Four counties were randomly selected from each category (as shown in Figure 2). Then, two townships were randomly selected from each sampled county. Next, four sample villages were randomly selected

from each sampled township. Finally, 10 family farms were randomly selected from each sampled village. Therefore, the sample for Henan province covered 20 counties, 40 townships, 80 villages, and 800 family farms. Overall, 800 questionnaires were distributed, and 653 valid questionnaires were returned. A validity rate of 81.6% was achieved after eliminating questionnaires that omitted key information or presented self-contradictory information (for instance, where age is less than the number of years of education).

In this paper, the data were collected through face-to-face interviews to reduce the response bias and improve the response rate. In the process of the interview, first, interviewers asked vegetable farmers whether they use GCTs, whether they have heard of GCTs for the vegetable plant, under what circumstances they are willing to adopt the technology and whether there are subsidies and training. For interviewees who answered seriously without contradictory words, we would allow them to fill in the questionnaire. Each interviewee would have about 20 min to fill in it. For those who are illiterate, interviewers completed the interview by asking for items in the questionnaire. In the process of inquiry, our interviewers did not convey any guiding information, to ensure the results are objective and fair. Second, interviewees were assured that they had the right to refuse the interview and told that interviewers were researchers rather than officials. In this way, the psychological burden of the interviewees was reduced. Additionally, they were told that the content of the questionnaire was closely related to their lives and the results of the interview were very useful for policy-making; as such, the interviewees would have a positive impression of our survey (Lou et al., 2021). This helped to improve the accuracy of their response. Moreover, we emphasized that the interview was completely anonymous and the results were for research purposes rather than commercial use so that the respondents knew that their privacy was well protected. After the interview, our interviewers would sort out and analyze the results, and delete those questionnaires with a high repetition rate and with many missing values. For controversial questionnaires, our three researchers discussed and determined whether the questionnaire should be left.

3.3. Sample description

As shown in Table 1, from the perspective of individual basic characteristics, in terms of gender, males accounted for 74.7% and females accounted for 25.3%. In terms of age, farmers aged 40–50 accounted for the highest proportion (67.69%), with an average age of about 46.04. In terms of education level, farmers' average education years is about 10.7, and the education level is generally low. The main characteristics of the samples and their distribution are shown in Table 1. In addition, the number of farming households with more than 2 members accounted for 58.65% of the total sample, indicating that the number of farming households with more than 2 members was relatively small. The number of farming households joining cooperatives accounted for 47.47% of the sample, indicating that the current farming households are not highly organized. The number of farming households that often participate in agricultural orders only accounts for 2.76% of the total sample, and the degree of farming households' participation in agricultural orders is generally low. Furthermore, the statistical results showed that 88.82% of the farmers adopted green prevention and control technologies (GCTs). Among them, 34.61% of the farmers occasionally and frequently adopted GCTs, 22.97% of the farmers often adopted it, and only 31.24% of the farmers always adopted it (the sum of the three = 88.82), which shows that the proportion of farmers adopting GCTs in the sample area is high, but the degree of adoption is not high. Then, the motives were measured by exploratory factor analysis using SPSS 24.0 software. The measured KMO value was 0.676, and the Bartlett sphericity test passed the 1% significance test, indicating that factor analysis could be conducted. Two common factors with characteristic roots greater than one were also obtained. The variance contribution rate of the common factor 1 was 43.796%, which focused on the adoption of GCTs is conducive to improving vegetable quality, obtaining green certification, increasing planting income and saving production costs, i.e., farmers' "economic efficiency motivation." The contribution rate of variance of common factor 2 is 26.622%, which focuses on the local penalties for agricultural surface pollution and government subsidies for green and efficient technology promotion services, i.e., farmers' "environmental regulatory arbitrage motivation." The composite index value was obtained: Motivation = (economic efficiency motivation x 43.796% + regulatory arbitrage motivation x 26.622%)/70.418%.

3.4. Model construction

3.4.1. Baseline model

The explanatory variables in this paper belong to ordered multi-classification variables. Referring to Shi and Zhang (2022)'s method of dealing with the problem that the explained variables are ordered multi-classification variables, this paper uses the ordered logistic regression model to analyze the adoption behavior of farmers' GCTs. The specific expressions are as follows.

$$\mathrm{Logit}(\mathrm{P}i) = \mathrm{L}n\left[\mathrm{P}(y \le i) / \mathrm{P} \ge (\mathrm{Y}j + i)\right] = \alpha i + \beta x \qquad (1)$$

where $\mathrm{P}j = \mathrm{P}(y = j)$; $\mathcal{X}$ is the variable affecting the adoption behavior of green control technology GCTs by farmers; β is the regression coefficient corresponding to $\mathcal{X}$; and α_i is the intercept of the model. After obtaining the parameter estimates, the probability of occurrence of $\mathrm{Y} = i$ can be obtained by the following equation.

$$\mathrm{P}(y \le j / x) = \frac{e^{-(\alpha+\beta xi)}}{1 + e^{-(\alpha+\beta xi)}} \qquad (2)$$

TABLE 1 Variable definitions and descriptive statistics.

Variable type	Variable		Measure	Mean	Std. dev.
Dependent variable	GCTs adoption behavior		1 = Never, 2 = Occasionally, 3 = Frequently, 4 = Often, 5 = Always	3.485	1.356
Main independent variable	Information acquisition	Access to information: government, cooperatives, neighborhoods, media	0 = None, 1 = 1 information channel, 2 = 2 information channels, 3 = 3 information channels, 4 = 4 information channels	2.613	1.366
	Motivation	Conducive to improving the quality of vegetables	1 = yes; 0 = no	0.557	0.497
		Conducive to obtaining green certification	1 = yes; 0 = no	0.620	0.486
		Conducive to increasing planting income	1 = yes; 0 = no	0.606	0.489
		Conducive to save production cost	1 = yes; 0 = no	0.515	0.500
		The government subsidizes green technology promotion services	1 = yes; 0 = no	0.596	0.491
		There are local penalties for agricultural non-point source pollution	1 = yes; 0 = no	0.455	0.498
	Behavioral skills	Participate in various agricultural cultivated land protection technology training	1 = yes; 0 = no	0.470	0.499
		Often communicate with agricultural technicians	1 = yes; 0 = no	0.455	0.498
		Often study publicity materials of green prevention and control technology	1 = yes; 0 = no	0.459	0.499
Control variable		Gender	1 = male; 0 = female	0.747	0.435
		Age	Age in 2021	46.044	5.481
		Educational level	Years of education	10.698	2.819
		Number of laborers	Total number of family vegetable planting laborers	2.538	0.667
		The main relatives are party members or village cadres	1 = yes; 0 = no	0.158	0.365
		The local government has incentives for green planting	1 = yes; 0 = no	0.492	0.500
		Degree of participation in agricultural orders	1 = Never, 2 = Occasionally, 3 = Frequently, 4 = Often, 5 = Always	1.995	0.901

3.4.2. Mediating effect test

The mediating effect refers to the fact that the relationship between variables is not a direct causal chain but can be influenced indirectly through other variables. Compared with the direct influence relationship between variables, the mediating effect model can analyze the influence process and the mechanism of

variables more deeply. Given that the mediating variables "motivation" and "behavioral skills" are continuous variables, the transmission mechanism of motivation and behavioral skills in influencing farmers' adoption of GCTs is tested by the stepwise regression method according to Wen and Ye (2014). The model was constructed as follows.

$$Y = cX + e1 \tag{3}$$

$$M = aX + e2 \tag{4}$$

$$Y = c'X + bM + e3 \tag{5}$$

where X is the independent variable, M is the mediating variable, and Y is the dependent variable. e_1, e_2, e_3 are the regression residuals. c is the total effect of the independent variable on the dependent variable; a is the effect of the independent variable on the mediating variable; b is the effect of the mediating variable on the dependent variable; and c′ is the direct effect of the independent variable on the dependent variable.

4. Results and analysis

4.1. Baseline model regression

4.1.1. Analysis of model results

Stata15.0 was used to analyze the data in the paper. The model calculation results show (Table 2) that the behavior logic of farmers' GCTs adoption behavior follows the IMB model, and the significance of the log-likelihood ratio test of the model was found to be less than 0.05, indicating that the overall fit of the model was good.

As seen in Table 2, Model 1 shows that the information acquisition channels of farmers have a direct driving effect on the GCTs adoption behavioral response ($\beta = 0.917$, $p < 0.000$), indicating that the wider the source of information is, the greater the range of effective information that farmers are exposed to in the market, and with the transfer of information, farmers will tend to compare and imitate the behavior of others, resulting in a convergence of GCTs adoption behavior among farmers (hypotheses H1was supported). Model 2 shows that motivation has a direct driving effect on farmers' GCTs adoption behavior ($\beta = 0.808$, $p < 0.000$), indicating that maximizing economic benefits and minimizing risks are the fundamental motivations for farmers to produce, and farmers will tend to adopt GCTs to avoid losses (hypotheses H2 was supported). Model 3 shows that the behavioral skills of farmers have a direct driving effect on the GCTs adoption behavioral response ($\beta = 0.877$, $p < 0.000$), indicating that mastering GCTs can effectively improve farmers' adoption behavior (hypotheses H3 was supported).

Furthermore, in Models 1–3, the control variables "participation in agricultural orders, government incentives for green farming and the main relatives are party members or village cadres" passed the significance test. First, participating in agricultural orders can reduce production risks and additional costs, which meet the production requirements of large-order farmers, so farmers who have participated in order or standardized production will be more inclined to adopt GCTs in agriculture. In addition, based on economic incentives, constraints and punishments, government incentives with the support of production technology, insurance, service and sales have a significant role in promoting GCTs adoption behavior. Moreover, from the perspective of social relations, if farmers have close relations (relatives, good friends, partners, etc.) with village (town) cadres and rural talents, these relations may help farmers understand and accept GCTs information, and then affect farmers' willingness to adopt GCTs.

TABLE 2 Estimation of model results.

Variable type	Model 1	Mode 2	Mode 3
Information acquisition	0.917***(0.064)		
Motivation		0.808***(0.106)	
Behavioral skills			0.877***(0.081)
Gender	0.174 (0.172)	0.082 (0.169)	0.112 (0.168)
Age	0.005 (0.014)	0.012 (0.013)	−0.00009 (0.013)
Educational level	0.008 (0.026)	0.021 (0.026)	0.037 (0.026)
Number of laborers	0.022 (0.111)	0.043 (0.107)	−0.013 (0.107)
Degree of participation in agricultural orders	0.243***(0.088)	0.434***(0.086)	0.469***(0.087)
The main relatives are party members or village cadres	0.242 (0.205)	0.155*(0.204)	0.207 (0.202)
The local government has incentives for green planting	0.509***(0.148)	0.541***(0.144)	0.667***(0.145)
Log-likelihood	−876.245	−964.528	−930.046
Pseudo R2	0.134	0.046	0.081
Prob>chi2	0.000	0.000	0.000

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$, standard errors in parentheses.

4.1.2. Robustness test

To ensure the robustness of the results, the empirical results are tested in the paper. First, the robustness of the model is tested by replacing the model with the ordered Probit model. Second, the latent variables in each core variable are changed for testing. For example, the variable "access to information: government, cooperative, neighborhood" is replaced with "access to information: government, cooperative, neighborhood." In the motivation, the core latent variables of "no additional cost for green control technology adoption" and "local penalties for agricultural surface pollution," which represent the motivation of economic benefits and environmental regulatory arbitrage motivation, were removed. In the behavioral technique, the core latent variable of "participation in various types of training such as agricultural farmland protection technology" was removed. As shown in Table 3, the results obtained by the two methods are basically consistent with the results in Table 2, indicating that the estimation results are robust.

4.2. Results of the mediating effect test

The results of mediating effect test are reported in Table 4.

(1) In the path of "information-motivation-farmers' GCTs adoption behavior," the coefficient value of information on motivation is 0.134 ($p < 0.000$), suggesting that information acquisition has a significant positive effect on farmers' GCTs adoption motivation (Hypothesis H4 is further verified). In addition, the coefficient value of information on farmers' GCTs behavior is 0.569 ($p < 0.000$), and information still had a significant positive effect on farmers' GCTs ($\beta = 0.528$, $p < 0.000$) after the inclusion of motivation variables. Thus, it is seen that the mediating effect of motivation on the relationship between information and farmers' GCTs is significant, and the mediating effect is 0.041 (hypothesis H5 is valid).

(2) In the path of "information-behavioral skills-farmers' GCTs adoption behavior," the coefficient value of information on behavioral skills is 0.222 ($p < 0.000$), suggesting that information acquisition has a significant positive effect on farmers' GCTs behavioral skills (Hypothesis H6 is further verified). In addition, information still had a significant positive effect on farmers' GCTs adoption behavior ($\beta = 0.476$, $p < 0.000$) after the inclusion of behavioral skills variables, indicating that information acquisition can act on farmers' GCTs adoption behavior through behavioral skills mediation, and the mediating effect was 0.093 (hypothesis H7 is valid).

(3) In the path of "motivation-behavioral skill farmers' GCTs adoption behavior," the coefficient value of motivation on behavioral skill is 0.444 ($p < 0.000$), suggesting that motivation has a significant positive effect on farmers' GCTs behavioral skills (Hypothesis H8 is further verified). In addition, motivation positively influences farmers' GCTs adoption behavior ($\beta = 0.555$, $p < 0.000$), and motivation still has a significant positive influence on farmers' GCTs adoption behavior ($\beta = 0.314$, $p < 0.000$) after the inclusion of behavioral skill variables, indicating that motivation can act on farmers' GCTs adoption behavior through behavioral skills mediation, and the mediating effect is 0.241 (hypothesis H9 is valid).

Then, the robustness test of the mediating effect was conducted using bootstrap (n = 5,000). The standard of the test is to see whether the confidence interval contains 0. If it does, the original hypothesis should be rejected. As seen in Table 5, the results obtained were generally consistent.

5. Conclusion and discussion

5.1. Conclusion

Comprehensive promotion of agricultural GCTs is an important measure to ensure the safety of the agricultural ecological environment and achieve high-quality agricultural development. However, due to the unknown risks and information asymmetry of new technologies, the actual degree of adoption by "rational" farmers is not high. To further promote the comprehensive promotion of GCTs in agricultural production, the search for effective ways to improve farmers' adoption behavior of GCTs has become the core issue of the current research. Unlike the direct linear analysis of farmers' GCTs adoption behavior in the previous literature, this paper takes behavioral intervention as

TABLE 3 Robustness test results.

Variable type	Ordered probit test			Variable replacement test		
	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Information acquisition	0.535***(0.035)			1.292***(0.090)		
Motivation		0.473***(0.061)			0.710***(0.080)	
Behavioral skills			0.510***(0.046)			0.738***(0.077)
Log likelihood	−870.924	−963.646	−930.560	−869.818	−952.755	−945.495
Pseudo R2	0.139	0.047	0.080	0.140	0.058	0.065
Prob>chi2	0.000	0.000	0.000	0.000	0.000	0.000

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$, standard errors in parentheses.

TABLE 4 Mediating effect estimation results.

Variable type	GCTs adoption behavior	Motivation	GCTs adoption behavior	Behavioral skills	GCTs adoption behavior	GCTs adoption behavior	Behavioral skills	GCTs adoption behavior
Information acquisition	0.569***	0.134***	0.528***	0.222***	0.476***			
	0.032	0.020	0.032	0.028	0.031			
Motivation			0.307***			0.555***	0.444***	0.314***
			0.060			0.069	0.052	0.067
Behavioral skills					0.420***			0.542***
					0.042			0.049
Control variables	Controlled			Controlled		Regression result		

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$.

TABLE 5 Results of bootstrap robustness test.

Influence path	Effect	Regression coefficient	SE	95% CI	
				LLCI	ULCI
Information Acquisition→Motivation→Farmers' GCTs Adoption Behavior	Total effect	0.569	0.032	0.507	0.631
	Direct effect	0.528	0.032	0.465	0.591
	Indirect effect	0.041	0.011	0.022	0.064
Information Acquisition→Behavioral Skills→Farmers' GCTs Adoption Behavior	Total effect	0.569	0.032	0.507	0.631
	Direct effect	0.476	0.031	0.415	0.536
	Indirect effect	0.093	0.015	0.066	0.125
Motivation→Behavioral Skills→Farmers' GCTs Adoption Behavior	Total effect	0.555	0.069	0.419	0.690
	Direct effect	0.314	0.067	0.183	0.445
	Indirect effect	0.241	0.034	0.177	0.308

the key to determining the behavior change from the root of the problem and analyzes farmers' GCTs adoption behavior based on the "information-motivation-behavior skill" (IMB) intervention model (Fisher and Fisher, 1992, 2000; Fisher et al., 2006, 2014) and draws the following main conclusions.

First, a total of 88.82% of farmers in the sample area actively adopted GCTs, but the adoption level of GCTs was low, with only 30.7% of farmers regularly adopting GCTs. Second, information, motivation, and behavioral skills have significant positive effects on farmers' adoption behavior of GCTs. It was found that farmers with wide access to information ($\beta = 0.917$, $p < 0.000$), strong behavioral motivation ($\beta = 0.808$, $p < 0.000$), and better mastery of agricultural technology ($\beta = 0.877$, $p < 0.000$) were more likely to adopt GCTs, which is consistent with the prediction of the classical IMB model (Fisher and Fisher, 1992, 2000; Fisher et al., 2006, 2014; Seacat and Northrup, 2010; Ehret et al., 2021). Furthermore, motivation and behavioral skills are activated through information, and the more information access channels there are, the greater the activation and the stronger the facilitation effect on farmers' green control technology adoption behavior, which is consistent with the findings of Shi and Zhang (2022) and Zhang et al. (2020). In addition, motivation also has a facilitating effect on behavioral skills ($\beta = 0.444$, $p < 0.000$), which can indirectly affect farmers' GCTs adoption behavior through behavioral skills. In summary, this study confirms that the theoretical framework of the information–motivation–behavioral skills (IMB) model is applicable to the study of vegetable farmers' adoption behavior of green prevention and control techniques (GCTs); specifically, that the adoption of the behavioral intention of vegetable farmers is affected by GCTs information acquisition, adoption motivation and behavior skills. This research broadens the research scope of IMB as well as sustainable technologies such as green prevention and control techniques (GCTs). It also draws more attention to the academic study of vegetables and will hopefully motivate later generations to further study the behavior of vegetable farmers.

5.2. Theoretical contributions

Our study makes several contributions to the literature. First, in response to some studies (Lou et al., 2021; Yu et al., 2021a; Niu et al., 2022) that called for future research examining factors influencing farmers' intention to adopt pro-green control technology using various theoretical frameworks and diverse populations, our study is the first to use the information–motivation–behavioral skills (IMB) model as the theoretical

framework for exploring factors influencing vegetable farmers' GCTs adoption behavior. Secondly, the findings are consistent with the IMB model (Seacat and Northrup, 2010; Ehret et al., 2021), supporting the model's utility in explaining green prevention and control techniques behavior. More specifically, our study contributes to the literature by validating the utility of the IMB model in predicting and explaining vegetable farmers' GCTs adoption behavior in the context of China, where the use of GCTs remains mainly experimental and implemented at a small scale, and providing a theoretical ground for future research. Finally, previous studies offered a holistic understanding of pro-green control technology adoption behavior by exploring farmers' own resource endowment (Xiong and He, 2020), social networks (Gao et al., 2019a), economic incentives (Geng et al., 2017) and technical characteristics (Gao et al., 2020; Liu et al., 2022) in general. By focusing on psychologically-based interventions, our study contributes to the existing body of literature in the field of green production. Among the three IMB predictors, information acquisition had the most dominant and direct effect on pro-green control technology adoption behavior. It is also worth noting that both direct and indirect effects were statistically significant. Our results support the practicability of applying the IMB model to predict green prevention and control techniques adoption intentions, indicating that the IMB model can be used as a framework for developing educational interventions promoting pro-green control technology by farmers.

5.3. Policy recommendations

This study can help decision-makers, such as people in the Chinese government, better understand the factors affecting vegetable farmers' adoption behavior of green prevention and control techniques (GCTs) and make targeted GCTs extension policies. First, the policymakers should strengthen the construction of rural information resource-sharing projects, improve information infrastructure, and meet the information needs of farmers as much as possible. In addition, carry out special education and training on information literacy that meets the characteristics of farmers to effectively improve their information literacy so that rich, timely and accurate information can help farmers reduce costs and increase income to the greatest extent. Second, strengthen the publicity and promotion of GCTs, mobilize farmers to participate in the enthusiasm, and take the initiative to learn and master green prevention and control technology. At the same time, agricultural technology subsidies should be increased, the perceived risk level of farmers' adoption of GCTs should be weakened, and farmers should be guided to correctly understand the effect of yield increase brought by green prevention and control technology. Third, the reform of the agricultural extension system should be deepened, technical guidance and training in green prevention and control for farmers should be strengthened, farmers' scientific knowledge of GCTs should be improved, and the adoption rate of GCTs should be increased among farmers. Moreover, although policy support or technology information service is important, the effect of policy or technology implementation needs more attention. We need to form a vertical information feedback mechanism, effectively understand the real needs and difficulties of farmers in technology and policies, and provide farmers with full-course or phased services. Environmental pollution caused by pesticide abuse in the agricultural sector has also become a major problem facing countries worldwide. Our study is relevant in these times, and our results suggest the need for a transition to green prevention and control techniques (GCTs), the reduction of pesticide use, and the implementation of government programs. It is crucial for the government to strongly support and promote farmers' awareness to encourage the transition to green production. This paper suggests strategies for the Chinese government to potentially influence vegetable farmers' behavior; however, we believe that green production technology has no international boundaries and that other governments can also take corresponding measures to strengthen the promotion and application of GCTs.

5.4. Research limitations and outlook

Our study aims to solve the problem of environmental pollution and pest invasion and provide strategies for government departments to promote the adoption of green prevention and control techniques. By doing these, we strive to achieve the goal of full coverage of GCTs and sustainable development in the agricultural section worldwide in the future. GCTs is the localized version of IPM in China. Similar to China, other developing countries are also facing the challenges of chemical pesticide overuse and low levels of IPM adoption. Thus, this study's analytical framework may be applicable to other developing countries, and the conclusions may have important implications for these countries as they implement IPM promotion policies. Of course, we have to acknowledge that this study has some limitations that need to be improved upon in future research work. First, the findings of this paper are based on survey data of vegetable farmers in Henan Province, but it remains to be seen whether consistent findings can be drawn in other regions of China. Second, GCTs is a complex technology package that includes multiple seed technologies. This paper only examines whether farmers adopt GCTs, and further research could include specific GCTs sub-technologies in the analysis framework to explore the contribution of information accessibility to farmers' GCTs adoption behavior. Third, it is important to note that the article treats farmers as the main body of adoption of agricultural green prevention and control technologies, but rural environmental management and agricultural green prevention and control technology promotion cannot be solved by farmers alone but also requires coordination among various sectors, such as

government, the market, and the rural communities. Further research and improvement are needed on how each sector can "play" their respective roles to give full play to the "information-motivation-behavior skills" to promote farmers' adoption of green control technologies. Furthermore, to best strengthen IMB interventions, future research will also need to consider additional contextual and individual-level factors that may moderate different IMB components, such as farmers' value demands, attention allocation, risk aversion and business scale.

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.

Ethics statement

Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

TC and XL: conceptualization, data curation, and writing-review and editing. XL and ZW: methodology. TC: formal analysis and writing–original draft preparation. TC, ZW, and JZ: investigation. ZW: supervision. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

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Explaining the ranchers' behavior of rangeland conservation in western Iran

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Rangeland are one of the most important natural habitats for the protection of living and non-living organisms. Degradation of rangeland is one of the biggest threats to biodiversity loss. Ranchers', as the most important key stakeholders who have a direct relationship with rangelands, have put a lot of pressure on the rangeland sector in recent years, so that this natural habitat has been destroyed. Therefore, existing rangelands must be preserved to protect biodiversity. One of the most important strategies to protect rangeland is to change the behavior of ranchers to friendly and ecological behaviors in the environment. In this regard, this study was conducted with the general aim of explaining the ranchers' behavior of rangeland conservation in western Iran. The main research tool was a questionnaire whose validity was confirmed by a panel of experts and its reliability was confirmed by Cronbach's alpha coefficient. In this study, value-belief-norm (VBN) was used to identify research variables. The results showed that ranchers have used different behaviors to protect rangelands and egoistic behaviors are the main cause of the destruction of this natural habitat. In addition, the results of this study showed that the framework used was an efficient theory because it explains 53.9% of rangeland conservation behavior. Finally, in this study, based on the research findings, applied policies for the protection of natural rangelands were presented so that in addition to rangeland conservation, biodiversity can also be preserved.

KEYWORDS

rangeland protection, natural resources, livestock and rangeland balance, value-belief-norm, ranchers', Iran

Introduction

Nearly half of human societies depend on the products and services of the rangeland, the largest ecosystem on Earth (Eddy et al., 2017; Brunson et al., 2021). It is estimated that 30–50% of the world's land surface is covered by rangelands (Sugita et al., 2007; Dinan et al., 2021). In Iran, there are about 84.7 million hectares of grazingland, which accounts for 52% of the country's total land surface. The total

grazing area in Iran consisted of 8.5, 25.3, and 66.2% of dense, semi-dense, and low-density pasture, respectively (Asaadi and Yazdi, 2011; Karimi and Saghaleini, 2021). Rangeland is considered one of the most important sources of production in this country and plays a key role in supplying forage for domestic animals and food production (Karimi and Saghaleini, 2021; Savari and Zhoolideh, 2021; Savari and Moradi, 2022). Grazing land is therefore one of the most important natural resources of a country, providing the basis for other activities such as agriculture and animal husbandry. Hence, taking measurements to conserve these natural resources is of high importance (Noguera-Mendez et al., 2016). Rangeland ecosystems provide several key services, including medicinal plant production, forage provision, climate regulation, soil and water conservation, and environmental conservation (Prager et al., 2015). In recent decades, many efforts have been made to protect rangelands. For instance, the Returning Grazing Land to Grassland project was launched in 2003 (Wang et al., 2013). Nevertheless, these efforts have not been effective as the degradation of rangelands is increasing (State Forestry Administration [SFA], 2005, 2011, 2015). In the last three decades, Iranian rangelands have been destroyed to a greater extent than those of European and American countries, so that more than 20% have been destroyed quantitatively and qualitatively (Food and Agriculture Organization [FAO], 2013). There are 124 million livestock units in Iran, 83 million of which depend on Iranian rangelands. However, Iranian rangelands are only capable of feeding about 37 million livestock units within 7 months or about 24.6 million livestock units within a year. Consequently, Iranian rangelands are currently being used 2.2 times more than their allowable capacity (Karami et al., 2021). As a result, the imbalance between the livestock population and the tolerance capacity of Iranian rangelands has destroyed many grazing areas and subsequently eroded the soils (Savari et al., 2022a,b). Therefore, illegal grazing is the main cause of rangeland degradation (Noguera-Mendez et al., 2016; Wassie, 2020; Besada, 2021) because livestock grazing affects various components of rangeland ecosystems such as soil, water, floral composition, diversity, and forage quality on the performance of the whole ecosystem (Hein, 2006; Retzer, 2006; Eldridge et al., 2016; Lu et al., 2017; Karami et al., 2021). Intermittent grazing, on the other hand, is associated with a positive effect on plant traits and rangeland ecosystems. Seasonal grazing restricts the selection of grazing livestock, which reduces the production of invasive seeds and increases flowering traits such as plant growth and survival (Earl and Jones, 1996; Zhang et al., 2017). However, more than 70% of rangeland degradation is attributed to human activities, to improve rangeland conservation, ranchers in particular need to improve their environmental behavior (Food and Agriculture Organization [FAO], 2013; Lepak et al., 2021). According to this evidence, ranchers are more involved in the rangeland ecosystem than any other part of society and play a key role in its degradation and conservation (Folke, 2006; Kovács et al., 2021). Currently, pastoralist behavior in rangeland conservation is not well-studied (Lu et al., 2017; Ohta et al., 2020; Karami et al., 2021; Karimi and Saghaleini, 2021). What has been emphasized more in past studies has been the control of livestock farmers' behavior through incentives and restrictions (Katuwal, 2012; Kovács et al., 2021) and policy makers have planned without considering the viewpoints and attitudes of farmers. Meanwhile, examining people's views and norms precedes any activity in the field of environmental protection (Savari et al., 2022b).

The use of social-psychological models and theories is one of the most important methods for studying conservation behavior and its preventive factors (Turaga et al., 2010; Yazdanpanah et al., 2015; Savari and Gharechaee, 2020; Karimi and Saghaleini, 2021; Savari et al., 2022c). Environmental psychological studies are important because they show that sustainable behavior in the environment requires individuals to internalize norms and behaviors, as incentives and constraints cannot produce sustainable manners in them (Savari et al., 2022d). According to psychological theories, the pro-environmentally behavior of people is influenced by psychological factors such as attitudes, beliefs, feelings, norms, and values (Bagheri et al., 2019; Rezaei et al., 2019; Savari and Gharechaee, 2020). However, sociologists and psychologists have proposed various theories to study the environmental behavior of users, the most important of which are the following norm activation model (NAM) (Schwartz, 1977), theory of planned behavior (TPB) (Ajzen, 1991), and value-belief-norm (VBN) (Stern, 2000). Among these views, VBN received attraction due to its comprehensiveness, simplicity of variable measurement, emphasis on psychological aspects, especially internal values and beliefs, and relevance of variables to environmental factors (Chen, 2015; Lind et al., 2015; Veisi et al., 2020). Interestingly, only this theory considers the worldview of human ecology in nature (Chen, 2015). Thus, this study aimed to identify the factors that influence ranchers' behavior of rangeland conservation in western Iran. Two main objectives were pursued: (i) to use VBN ability in identifying the factors influencing rangeland protection behaviors, and (ii) to develop practical interventions to strengthen rangeland protection behaviors in Iran.

Theoretical framework

Value-belief-norm (VBN)

There are several approaches to explain human behavior in the use of natural resources such as water, forests, and rangelands. These methods are called logical and moral strategies with different assumptions (Steg and Vlek, 2009). Stern et al. (1999) combined values theory, including the New Ecological Paradigm (NEP) and NAM, and developed VBN theory to describe environmental behaviors. As a theory,

VBN examines normative factors that contribute to sustainable attitudes and behaviors (Fornara et al., 2016). VBN theory provides a causal chain of explanations for environmental behavior (Chou, 2014; Huffman et al., 2014; Stevenson et al., 2014) that moves from stabilized and permanent elements of personality and belief to a greater focus on the unfortunate consequences of one's values and personal responsibility to reduce risk (Chen, 2015; Lind et al., 2015).

As an moral approach, NEP emphasizes moderation and balance in the exploitation of nature because of the limitations it places on man's use of natural resources. In other words, its strategy considers humans as part of nature, in contrast to the prevailing paradigm, which is a rational approach (Dunlap et al., 2000). According to VBN theory, this view introduces different values for natural resources such as forests, rangelands, and water that determine the underlying attitude and behavioral framework of individuals toward the environment (Ibtissem, 2010). VBN assumes that personal moral norms are activated by individuals who become aware of the adverse impacts of certain environmental conditions that threaten their desired values. As a result, individuals take responsibility for these devastating consequences (Stern, 2000; Zhang et al., 2020).

The theory considers the variables of environmental values attitudes (altruistic, biospheric, and egoistic), beliefs, norms, and behaviors that have specific relationships (Stern, 2000; Bijani and Hayati, 2013). According to VBN theory, behavioral beliefs are based on biospheric, altruistic, and egoistic values (Stern, 2000; Chen, 2015). Altruistic and biospheric orientations positively influence behavioral beliefs, whereas egoistic orientations negatively influence them (Hiratsuka et al., 2018; Zhang et al., 2020). Egoistic people tend to evaluate environmental aspects based on how the environment affects them. In other words: If they understand that there is a cost to using protective behaviors in the environment, they should avoid them (Chen, 2015). Those who are altruistic, on the other hand, typically evaluate aspects of the natural environment based on benefits and costs to human groups (Cho et al., 2013). Biospheric people evaluate the environment based on the benefits and costs it has to the ecosystem. People who value natural resources and the environment are more likely to prevent threatening situations to the ecosystem (Chen and Chai, 2010). In other words, people's values influence their perceptions of the consequences of ecosystem change for themselves, for other people, and other species within the ecosystem (Stern and Dietz, 1994). The term environmental beliefs refer to a system of attitudes that determine an individual's norms toward the environment and are the guiding principles in interacting with the environment (Corral-Verdugo et al., 2003). People's beliefs and attitudes are the first things that affect the environment and determine their behavior toward it, as they specify how the different components of the ecosystem are valued (Wensing et al., 2019; Ranjbar and Naeimi, 2020). Consequently, understanding people's environmental beliefs and identifying the factors that influence them is critical to environmental behavior research (Budak et al., 2005). According to VBN theory, personal norms are a key factor that directly influences environmental behavior (Stern, 2000; Phipps et al., 2013; Chou, 2014). In fact, moral norms are an internal emotional concept that ethically compels one to take actions that are consistent with one's values (Karimi and Saghaleini, 2021). Moral norms refer to one's sense of moral commitment to do or refrain from doing certain things that lead to environmentally friendly behavior (Yuan et al., 2021). Finally, pro-environmental behavior in this theory refers to conscious actions of individuals toward the environment, which include a wide range of feelings, desires, and willingness to perform desired actions. These behaviors aim to minimize the negative impact of human activities on the environment and improve it (Savari et al., 2021). Therefore, research hypotheses were raised based on **Figure 1**:

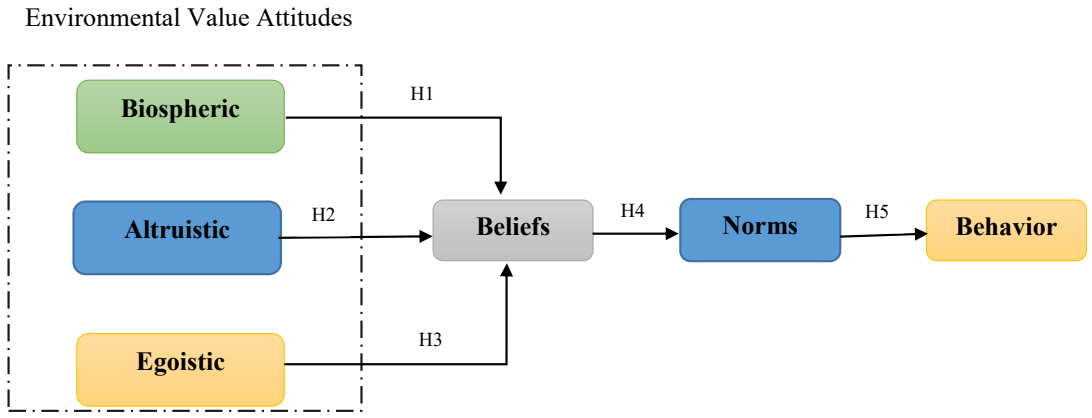

FIGURE 1
Causal chain of variables in VBN theory (Stern, 2000).

H1. Environmental value attitudes (Biospheric) has a positive and significant effect on beliefs.

H2. Environmental value attitudes (Altruistic) has a positive and significant effect on beliefs.

H3. Environmental value attitudes (Egoistic) has a negative and significant effect on beliefs.

H4: Beliefs has a positive and significant effect on norms.

H5. Norms has a positive and significant effect on rangeland protection behavior.

Materials and methods

Statistical population and sampling method

The statistical population of the study included all ranchers in the Saral district of Kurdistan province (Western Iran). According to Krejcie and Morgan (1970), 385 pastoralists in 15 villages were selected for the study. The sampling was conducted as a multistage stratified method with proportional allocation. This means, we tried to select the samples with proper distribution at the regional level so that the selected samples have high capability and reliability.

Study area

This investigation was carried out in 2020 and 2021 in a mountainous area approximately 35 km from Sanandaj (46450–46490 E and 35320 N–35360 N latitude) at an altitude of 2145 m (**Figure 2**). Saral district with an area of 1000 km^2 is located in Kurdistan province in western Iran. The average annual rainfall in this region is 480 mm (Iran Meteorological Organization, 2019). The climate in this area is cold and semi-arid. Saral has sandy loam soils which are excellent for grazing livestock (cattle, sheep, goats). Grazing (grazed sites) in this area by sheep, goats, cows and wild animals takes place from late April to late July without any additional management practices (Karami et al., 2021). Ecologically, Saral district is a safe habitat for diversity of plants and animals. Notably, this natural region has not been studied in an accurate and systematic way so far, and the majority of studies have focused on the plant and animal species in this region rather than the factors leading to degradation. The main occupation of the people in the Saral region is animal husbandry, as it is one of the most vulnerable areas for animal husbandry and is known as such throughout Iran (**Figure 2**).

Participants

According to the results, the average age of the participants was 52.44 ± 7.33 years. In addition, the results showed that the majority of the respondents 274 (71.16%) were male and 345 (89.61%) were married. In terms of education, results showed that among the respondents 73 were illiterate, 85 were primary school students, 82 were middle school students, 79 were graduate diplomas, and 66 received higher education. In addition, the average number of livestock was 27.22 sheep, 9.12 goats, and 1.24 cows. In addition, the livestock ranchers obtained more than 50% of the feed required by their domesticated animals from the rangelands and the animals grazed on the rangelands for more than 180 days.

Measurements

The main research tool was a questionnaire consisting of two general parts. The first part dealt with the personal and occupational characteristics of pastoralists. The second part consisted of 33 items measuring theoretical structures (VBNs) divided into six sections: (i) five items measuring biospheric value attitude, (ii) five items measuring altruistic value attitude, (iii) five items measuring evaluation of egoistic value attitude, (iv) five items measuring moral norms, (v) five items measuring behavioral beliefs, and (vi) eight items measuring rangeland conservation behaviors (RCB). Then, participants were asked to express their agreement or disagreement on the Likert scale (1-very low to 5-very high) to reduce statistical errors (Fornell, 1992). One of the most important points of this research was to measure the theoretical variables (VBN) using previous studies. The items of the questionnaire are shown in **Table 1**.

Validity and reliability of instrument

An expert panel reviewed the survey draft and questions before interviewing farmers to assess the general indicators measured. The panel included professors from the fields of agricultural extension and education, environment, psychology, social sciences, and agricultural sciences, and modifications were made based on their opinions until final approval. In addition, Cronbach's alpha coefficients and combined reliability were calculated to test the reliability of the questionnaire, which showed acceptable values (**Table 3**).

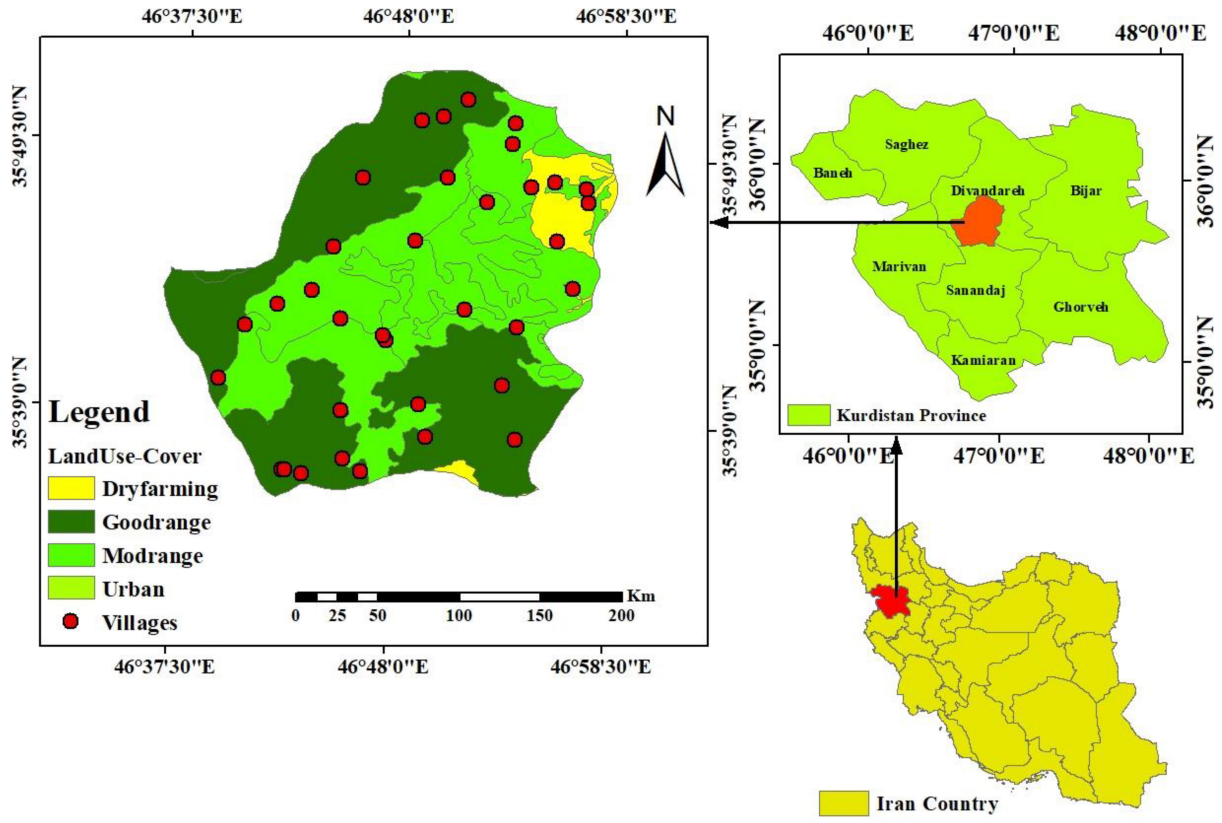

FIGURE 2
Study area.

Data analysis

Data were collected and analyzed using $SPSS_{23}$ and Smart Pls software. Structural Equation Modeling (SEM) is widely used by researchers because it provides the opportunity to test theories in the form of equations between variables. Moreover, this method can take into account the measurement error so that researchers can analyze the data by specifying the measurement error (Khoshmaram et al., 2020). Conventional models in SEM consist of two parts (Hair et al., 2014). A measurement model that examines how hidden variables are explained by explicit variables (questions), and a structural model that shows how hidden variables are related to each other (Hair et al., 2017). Furthermore, in this study, the ISDM1 index was applied to classify rangelands conservation behaviors (Gangadharappa et al., 2007):

$$\text{Low} : A < \text{Mean} - 1/2\,\text{Sd} \quad (1)$$

$$\text{Medium} : \text{Mean} - 1/2\,\text{Sd} < B < \text{Mean} + 1/2\,\text{Sd} \quad (2)$$

$$\text{High} : C > \text{Mean} + 1/2\,\text{Sd} \quad (3)$$

Results

Assessing the status of VBN model variables among respondents

As explained in the research method, the ISDM index was used to group the variables applied to the VBN model and rangelands protection behavior among ranchers'. According to the obtained results, the studied ranchers' did not show any considerable rangelands protection behavior, and only 24.94% had high protection behaviors, while the majority (48.57%) exhibited moderate rangelands protection behaviors. Moreover, two variables of VBN model, including moral norm and belief were at higher rank rather than other variables (**Table 2**).

Measurement model evaluation

This step determines whether the structures were measured accurately. To answer this question, the three phases of unidimensionality, reliability and validity, and discriminant validity were examined.

TABLE 1 Research measurement concepts and variables.

Construct	Measurement items	References
Biospheric	In addition to humans, plants, and animal species must also use the rangelands.	Dunlap et al., 2000; Chen and Chai, 2010; Hiratsuka et al., 2018; Veisi et al., 2020
	Livestock ranchers must also respect the rights of other plant and animal species.	
	I think we should behave fairly in nature.	
	Conserving the environment and rangelands takes precedence over livestock development.	
	Preserving vegetation and rangelands is more vital than forage supply for ranchers.	
Altrisitic	In my opinion, pasture conservation is a priority for ranchers.	Bijani and Hayati, 2011; Cho et al., 2013; Fornara et al., 2016; Zhang et al., 2020
	No rancher is allowed to destroy rangelands due to increase production (meat and milk), because it means losing the rights of other ranchers.	
	No rancher should leave his animals in the wilderness when it rains, because rangelands belong to all ranchers.	
	Grazing land belongs to all generations and we should not destroy it.	
	Since all ranchers have equal rights to the rangelands, no rancher can let as many cattle graze there as they want.	
Egoistic	Because of today's economic conditions, I cannot think of conserving the rangelands and their collective interests.	Bijani and Hayati, 2011; Chen, 2015; Hiratsuka et al., 2018; Veisi et al., 2020
	For me, increasing my livestock and income is more important than preserving rangelands.	
	Making more money is of greater importance than conserving rangelands.	
	I am allowed to use the rangelands as much as I want.	
	Providing forage for my livestock is more important than other ranchers.	
Moral norm toward pasture conservation	I think maintaining the rangelands is a moral obligation.	Stern, 2000; Savari et al., 2021
	I believe that the conservation of rangelands should not be neglected.	
	If I fail to protect rangelands, I feel guilty.	
	It is very important to me that ranchers protect their rangelands.	
	Ranchers help each other protect rangelands and interact well together.	
Belief in pasture conservation	I believe that rangelands are less abundant than in the past and we need to conserve them	Stern, 2000; Chen, 2015; Zhang et al., 2020
	I believe that overgrazing can destroy rangelands	
	I believe that rangelands do not have as much livestock capacity as in the past and we need to reduce the number of livestock	
	I believe that ranchers should not overuse grazing land to gain forage.	
	I believe that ranchers should avoid fixed grazing on rangelands.	
Rangeland conservation behaviors (RCB)	Reduction of livestock in grazing areas (balance between livestock and rangelands).	Karami et al., 2021; Karimi and Saghaleini, 2021
	Purchase of fodder from other places to reduce rangeland on rangelands	
	Use of rotational grazing instead of fixed grazing on rangelands.	
	Cultivation of compatible native plants in grazing areas	
	Avoid heavy grazing on rangelands	
	Prevent flowering and seed production of invasive and inappropriate grazing plants	
	Prevent livestock from entering rangelands too early in the spring.	
	Assist with grazing exclusion programs and removal of livestock from rangelands	

TABLE 2 Grouping the situation of VBN model variables among studied woman.

Variable	Mean	SD	ISDM category					
			Low		Medium		High	
			Frequency	Percent	Frequency	Percent	Frequency	Percent
Behavior conservation	2.88	0.688	102	26.49	187	48.57	96	24.94
Biospheric	2.69	0.715	114	29.61	201	52.20	70	18.19
Altrisitic	2.74	0.608	107	27.97	198	51.42	80	20.61
Egoistic	2.96	0.705	98	24.45	214	55.58	73	19.97
Moral norm	3.08	0.711	87	22.59	189	49.09	109	28.32
Belief	3.24	0.639	80	20.77	185	48.05	124	31.18

Unidimensionality

This step was assessed by factor loading and *t*-values. According to the values presented (Table 3), it can be claimed that the factor loading values presented for selected markers were statistically significant (above 0.6) and at the one percent error level ($P < 0.01$). The results confirmed the unidimensionality of the selected markers. Therefore, it can be concluded that the markers were selected correctly for the evaluation of research structures that measure exactly the same component.

Reliability and validity

In this step, the Combined Reliability (CR), Cronbach's alpha, and Average Variance Extracted (AVE) were examined. The results presented in Table 3 indicated that the CR of all the structures in the proposed research model was more than 0.60 and their Cronbach's alpha coefficients were more than 0.70. Moreover, the AVE for all structures of the proposed research model was above 0.50. Therefore, all latent variables had high reliability and validity, meaning that the items measuring the research structures were carefully selected and allowed the experiment to be repeated.

Discriminant validity

Diagnostic validity exists when questions measuring one variable are distinct or distinguishable from questions measuring other variables. Based on statistics, the research variables are of adequate diagnostic validity if the root mean of the calculated AVE variance between them is greater than the correlation between them (Fornell and Larcker, 1981). According to the results presented in Table 4; it can be seen that the root mean of the extracted variance for the research structures ($0.71 < \text{AVE} < 0.92$) was more than the correlation between them ($0.33 < r < 0.55$). This result confirmed the diagnostic validity of the structures in the proposed research model.

Evaluation of the research structural model

Various indicators were used in evaluating the fit of the research structural model (Table 5). Based on the proposed values of the presented indicators and the reported values, it can be claimed that the model had a good fit and the research hypotheses could be tested based on the model.

The measurement and structural models of the research were confirmed by confirmatory factor analysis. Then, to test the hypotheses of the proposed conceptual model of the research, the method of path analysis (structural model evaluation) was used. The path model of the research was represented by showing standardized loadings of the factors and the *t*-values in Figures 3, 4.

Test of the research hypotheses

In this step, the results of the final effect of the variables on the use of RCB were presented. The bootstrapping method was used to evaluate the significance of the path coefficient or beta. We used bootstrapping on 100 and 300 samples. According to the results, the significance of the parameters did not change in both cases and the results were valid. This is because the sample size did not affect the significance of the relationships between the variables, except for the value of the t-statistic. Therefore, regression models could be used to test hypotheses. The results showed that all research hypotheses were confirmed based on the predicted relationships. In addition, the research variables were able to explain 53.9% of the variance of RCB (Table 6).

Discussion

This study investigated the factors influencing the use of RCB among ranchers in western Iran using the VBN psychological model. In western Iran, this study represented the first attempt to protect rangelands, as past studies on pasture conservation have paid less attention to pastoralists who have a very close relationship with rangelands. Previous studies have focused on restrictions and incentives to examine ranchers' behavior. Because there was a belief that rangelands can be preserved through proper grazing exclusion and demarcation, so psychological studies were rarely considered. Recently, more attention has been paid to environmental psychology

TABLE 3 The results of fit of measurement models.

Constructs	Constructs	λ	*t*	Reliability and validity statistics
	BI1	0.833	28.241	AVE: 0.671
	BI2	0.882	39.714	CR: 0.919
Biospheric	BI3	0.876	29.404	α: 0.887
	BI4	0.829	20.929	
	BI5	0.683	12.483	
Altruistic	AL1	0.790	26.157	AVE: 0.573
	AL2	0.620	8.851	CR: 0.886
	AL3	0.679	10.816	α: 0.788
	AL4	0.794	17.730	
	AL5	0.781	14.690	
Egoistic	EG1	0.654	11.821	AVE: 0.589
	EG2	0.801	24.159	CR: 0.853
	EG3	0.766	16.159	α: 0.807
	EG4	0.797	23.611	
	EG5	0.736	14.750	
Beliefs	BE1	0.854	34.992	AVE: 0.618
	BE2	0.846	23.154	CR: 0.867
	BE3	0.762	18.529	α: 0.819
	BE4	0.769	15.835	
	BE5	0.609	10.481	
Norms	NO1	0.729	18.841	AVE: 0.527
	NO2	0.757	15.613	CR: 0.822
	NO3	0.765	17.147	α: 0.771
	NO4	0.675	11.170	
	NO5	0.704	13.811	
Behavior	BEH1	0.746	18.247	AVE: 0.577
	BEH2	0.840	26.908	CR: 0.903
	BEH3	0.802	17.216	α: 0.873
	BEH4	0.768	18.259	
	BEH5	0.651	13.403	
	BEH6	0.701	13.477	
	BEH7	0.672	12.596	
	BEH8	0.670	11.216	

TABLE 4 Correlations with square roots of the AVEs.

Constructs	1	2	3	4	5	6
1-Biospheric	0.92[a]					
2-Altruistic	0.45**	0.88[a]				
3-Egoistic	0.55**	0.41**	0.88[a]			
4-Beliefs	0.43**	0.33**	0.37**	0.78[a]		
5-Norms	0.39**	0.42**	0.51**	0.35**	0.84[a]	
6-Behavior	0.45**	0.41**	0.42**	0.38**	0.36**	0.71[a]

[a]The square roots of AVE estimate. **Correlation is significant at the <0.01 level.

TABLE 5 Summary of goodness of fit indices for the measurement model.

Fit index	SRMR	D-G1	D-G2	NFI	RMS-theta
Suggested value	<0.1	>0.05	>0.05	>0.90	≤0.12
Estimated value	0.07	0.517	0.254	0.97	0.07

because researchers believe that the application of constraints and incentives cannot produce sustainable behavior in the environment. When those motivations and restraints are removed, people's behavior returns to its original state. As a result, there is now more focus on norms, attitudes, and beliefs of individuals that can influence sustainable behavior in the environment (Savari et al., 2022b). Since very little research has been conducted in this area, this study used VBN theory because this strategy contains value attitudes, beliefs, and moral norms in its structure to examine the factors that influence RCB. Since this study examined the various effective factors on RCB and provided new insights in this regard, its findings can fill the gap of previous research in the literature and assist countries involved in uncontrolled rangeland destruction. SEM was used to test the research hypotheses presented in the following order.

This study showed that VBN theory was an effective model to examine the factors affecting RCB, not only because it confirmed all predicted relationships, but also because it was able to accurately predict more than 50% of RCB use. In addition, the results illustrated that environmental value attitudes can have a significant impact on beliefs about rangeland conservation. Our result is consistent with (Stern, 2000; Chen, 2015; Lind et al., 2015; Veisi et al., 2020). This finding can be explained by the fact that value attitudes are constantly mentioned as determining human behavior in the environment. In other words, people's behavior is influenced by their attitudes toward their natural environment (Savari and Gharechaee, 2020; Zobeidi et al., 2022a,b). For instance, according to a study on environmental behaviors, higher levels of education were associated with more positive attitudes toward environmental conservation and a higher likelihood of engaging in environmentally friendly behaviors (Kiatkawsin and Han, 2017). Among the dimensions of environmental value attitudes, those with a biosphere perspective were more likely to endorse rangeland conservation than those with other dimensions. This result is consistent with studies (Chen, 2015; Yeboah and Kaplowitz, 2016; Kiatkawsin and Han, 2017) and confirmed the research hypothesis (1). This can be explained by the fact that people with a biospheric perspective are concerned not only about other people, but also about the environment and other living organisms, and always strive to affect them negatively as little as possible

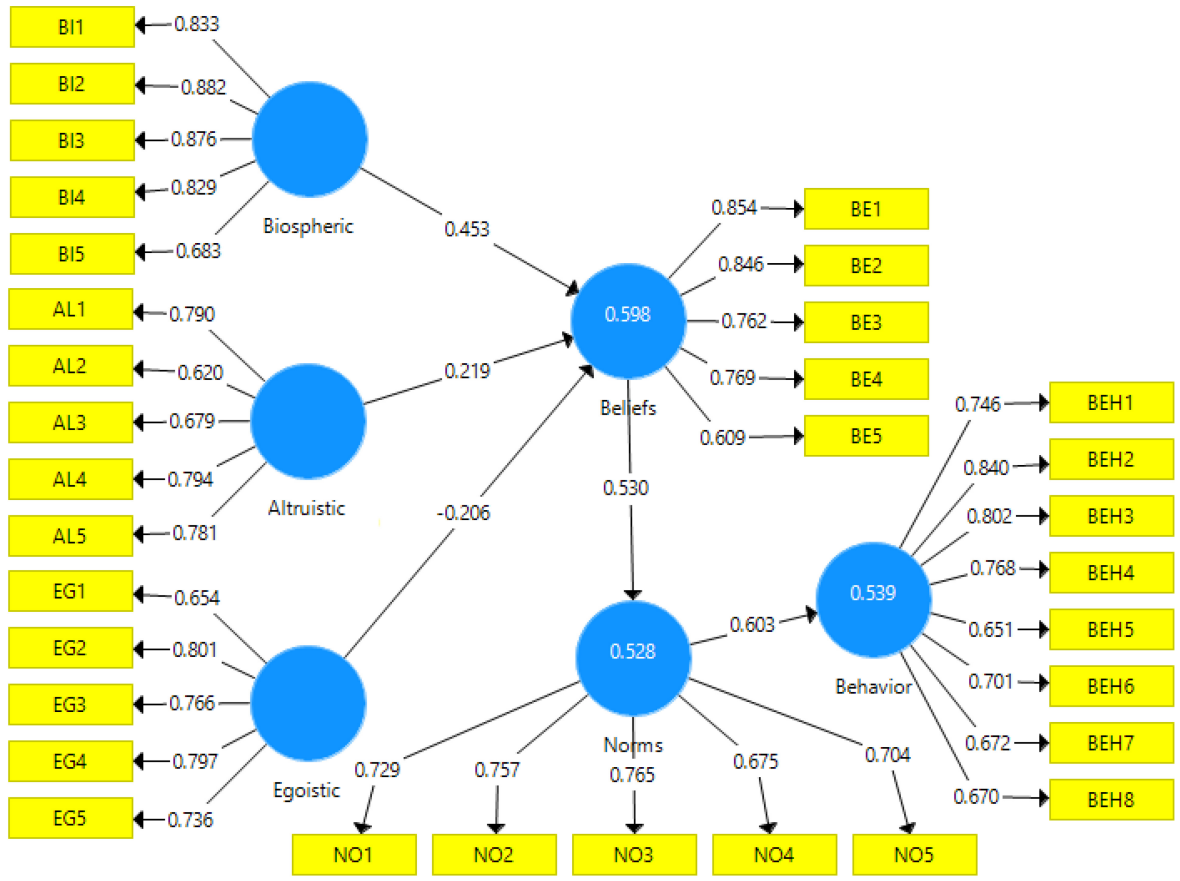

FIGURE 3
Path model with standardized factor loadings.

(Yeboah and Kaplowitz, 2016). Therefore, pastoralists with a biospheric perspective are more attracted to RCB and have a positive attitude toward their relationship with the natural environment. Also, they believe that conserving rangeland should be prioritized for ranchers so that they can use the rangeland for the long term (Karimi and Saghaleini, 2021). Livestock owners who have a biospheric value perspective are long-term oriented and reject immediate benefits in the natural environment that could lead to environmental degradation. The second variable of environmental value attitudes associated with rangeland conservation behavior was altruism. This result was consistent with studies (Stern, 2000; Cho et al., 2013; Lind et al., 2015; Valizadeh et al., 2016). Researchers have found that value attitudes influence people's environmental beliefs and that people with altruistic beliefs permanently attempt not to harm others (Cho et al., 2013). They constantly try to consider the welfare of others (Stern, 2000). Thus, ranchers with an altruistic value attitude always strive not to adversely affect the welfare of other ranchers through their behavior, as they take into account the interests of other ranchers and try to act in an environmentally conscious manner. In addition, these people think about intergenerational equity and believe that rangelands belong to the next generation, so they avoid destructive behavior when using rangelands. A third variable that affects pasture conservation beliefs was egoistic value attitude, which had both negative and significant effects in this regard. This result confirmed the research hypothesis (3). Similarly, studies (Chen, 2015; Fornara et al., 2016; Valizadeh et al., 2016; Veisi et al., 2020) have also found that the egoistic value attitude negatively affect the environment. A person with this value perspective always prioritizes their personal interests over the preservation of the natural environment and other people (Veisi et al., 2020). Egoistic people do not adhere to an environmental ethic or behavior, always highlight their benefits first (Zhang et al., 2020), and act destructively in the natural world. In other words, they pose a constant threat to the environment (Hiratsuka et al., 2018). Therefore, ranchers with an egoistic perspective are those who use RCB less and constantly disturb the balance of grazing land and livestock in the environment. This leads them to increase their livestock numbers to increase profit. These ranchers are the biggest threat to rangelands. They need to increase their awareness and sense of responsibility. Researchers

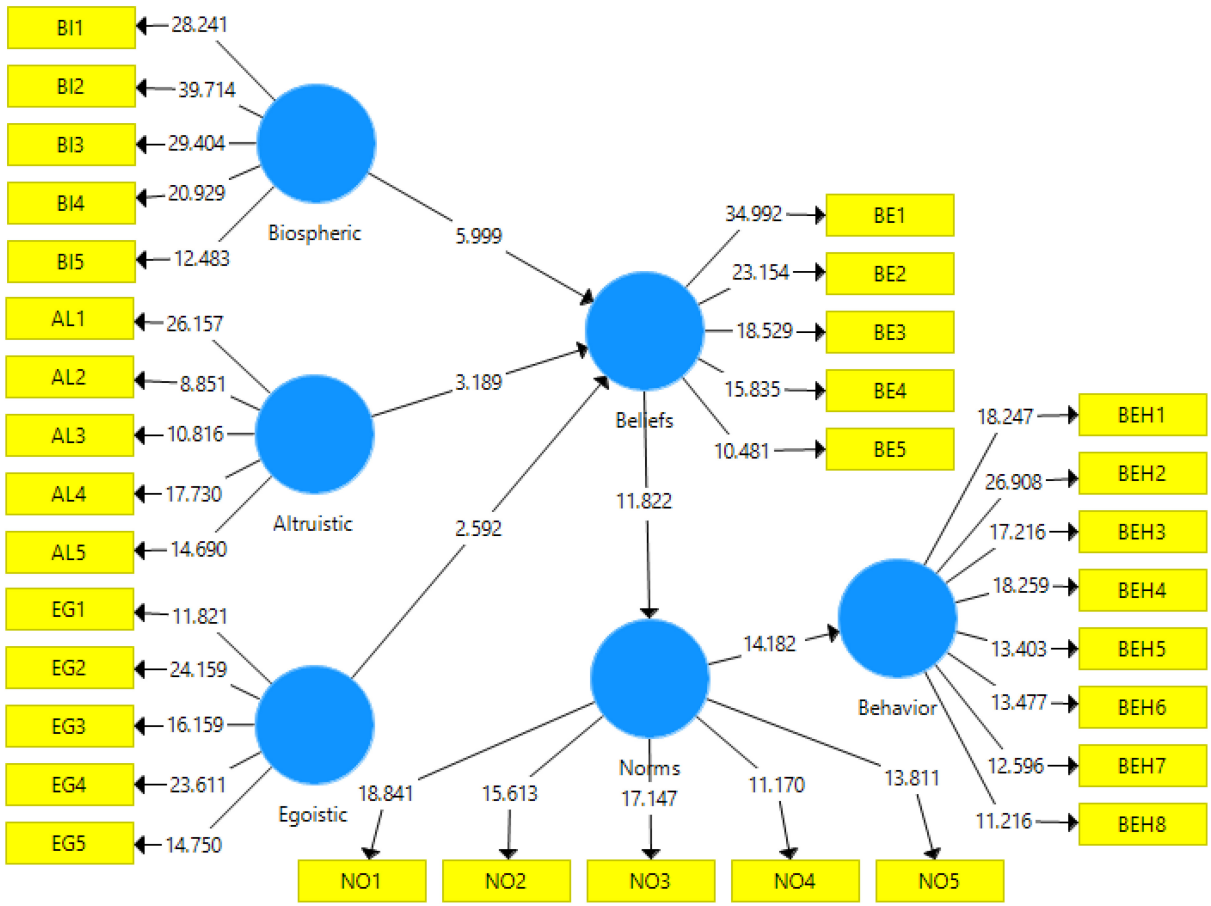

FIGURE 4
Path model with *t*-values.

have found that by strengthening the sense of responsibility of the profiteers, people can interact more ethically and expect environmentally friendly behavior (Chen, 2015). In addition, by increasing people's awareness of the impact of their harmful activities on the environment, their destructive activity in the environment can be reduced (Derckx, 2015).

Moreover, the results showed that individuals' beliefs could explain 52.8% of their moral norms. Thus, hypothesis (4) of the study was confirmed. Studies (Stern, 2000; Chen, 2015; Lind et al., 2015; Fornara et al., 2016; Zhang et al., 2020) support the findings of this section. Beliefs about environmental behavior are associated with a commitment to the use of natural resources, which can have a positive effect on environmental behavior (Savari et al., 2021). According to Stern (2000), to reduce environmental damage and prevent environmental degradation, it is necessary to strengthen people's beliefs about environmental conservation, because beliefs can always affect moral norms and sense of responsibility. Ranchers who believe in rangeland conservation, therefore, behave more responsibly in this regard. Finally, the results of the test of hypothesis (5) showed that moral norms influence farmers' RCB and can explain 53.9% of RCB. Our result accords with (Chen, 2015; Shin and Hancer, 2016; Valizadeh et al., 2016; Veisi et al., 2020). A possible explanation for these results could be that ranchers' adherence to moral principles is a good predictor of their protective behavior. Since farmers' behavior is subject to their internal norms, although it is influenced by several complex factors, it is largely determined by the observance of moral principles (Savari and Gharechaee, 2020).

TABLE 6 Results of research hypotheses.

Hypothesis	ƛ	t	Result	VIF	R^2	Q^2
H1: Biospheric→Beliefs	0.453	5.999	Confirm	1.685	0.598	0.154
H2: Altruistic→Beliefs	0.219	3.189	Confirm	1.524		
H3: Egoistic→Beliefs	−0.206	2.592	Confirm	1.638		
H4: Beliefs→Norms	0.530	11.822	Confirm	1.770	0.528	
H5: Norms→Behavior	0.603	14.182	Confirm	1.331	0.539	

The activation of personal norms occurs when the consequences of one's behavior lead to the destruction of the environment and the individual feels obligated to take responsibility for the natural environment (Stern, 2000). In a moral decision-making situation, people are aware that their actions affect the health of others. Therefore, they feel responsible for their actions and their consequences (Klöckner, 2013). In explaining and predicting behaviors whose consequences go beyond the individual level, such as environmental behaviors, moral norms play an important role (Mullan et al., 2015) and they are one of the most important predictors of environmental behaviors (Shin and Hancer, 2016).

Policy implication

In this stage, it can be claimed that ranchers who feel morally obligated to care for the range will exhibit the most sustainable behaviors in the natural environment because they feel responsible for the actions and consequences of their behavior and always attempt to not let their behavior lead to negative consequences for the range. If these people receive specific training, they can be used as nature helpers to promote safe behaviors in the environment. In addition, policymakers are advised to provide ranchers with alternative sources of income so that they will not be heavily dependent on grazing lands. This is because people with egoistic value attitudes are too dangerous to rangelands to avoid the overuse of livestock by engaging in other activities. The development of rangeland conservation cooperatives is another important rangeland conservation strategy. The establishment of organizations can undoubtedly develop norms for rangeland conservation among ranchers. In the study area, which covers more than 1000 km^2, rangeland cooperative is not active and policymakers did not pay attention to it. Another important solution in this area may be the development of grazing licenses for ranchers, which must specify the number of domesticated animals with grazing capacity and monitor them to prevent excessive expansion of livestock.

Conclusion and limitations of the research

The results of this study revealed that VBN theory was an effective strategy to explain RCB among ranchers in western Iran, which clarified more than 50% of rangeland conservation behavior. This theory reflected the significant influence of psychological models in explaining pastoralists' behaviors, which have not received much attention in previous research. Consequently, policymakers need to consider these factors when making appropriate decisions. Finally, several important limitations need to be considered. First, some of the variances have not yet been explained. Although psychological models explained a significant portion of the RCB variance, further research may identify other cognitive-behavioral factors. Second, only the VBN theory was examined in this study. For future research in this area, it is recommended that other major psychological theories be examined to identify the most important theories. A third limitation was the overemphasis on psychological factors. It is suggested that future research should also consider other economic and social factors to develop comprehensive and important rangeland conservation planning by ranchers.

Data availability statement

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

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

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

Publisher's note

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The effect of perceived value on farmers' livestock manure resource utilization behavior: Evidence from Shandong, China

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Introduction: The rapid development of animal husbandry has brought many problems such as ecological environmental pollution and public health damage. The resource utilization of livestock manure is the key way to deal with the above crisis and turn waste into treasure.

Methods: Based on the theory of perceived value, this paper uses multi-group structural equation model to explore the driving mechanism of perceived value on the resource utilization behavior of livestock manure.

Results and discussion: The results showed that: (1) The resource utilization behavior of livestock manure followed the logic of "cognitive level → cognitive trade-off → perceived value → behavioral intention → behavioral performance." Perceived benefit and perceived risk have positive and reverse driving effects on perceived value, respectively. Perceived value has a positive driving effect on behavioral intention. The behavioral intention has a positive driving effect on utilization behavior. (2) Among the observed variables of perceived benefits, ecological benefits have the greatest impact; Among the observed variables of perceived risk, economic risk has the greatest impact. Among the observed variables of perceived value, Significance cognition has the greatest influence. Among the observed variables of behavioral intention, utilization intention has the greatest influence. (3) The perceived value has a differential effect on the utilization behavior of livestock manure resources of different part-time farmers, and the driving effect is more obvious for full-time farmers.

Conclusions: Therefore, it is necessary to improve the resource utilization system of livestock manure, increase the channel for realizing the output of manure resources, strengthen technical assistance and policy subsidies, and implement policies according to local conditions to improve the overall perceived value of farmers.

KEYWORDS

perceived value, livestock manure, resource utilization of manure, Concurrent business, Multi-group SEM

1. Introduction

The rapid development of global animal husbandry not only meets the needs of a high-quality diet but also produces a large amount of livestock manure. Livestock manure, as the focus of agricultural non-point source pollution prevention and control (Li et al., 2019), will not only produce air pollution, soil destruction, water quality deterioration, and other environmental problems but also cause harm to human health. Studies have found that in low- and middle-income countries, livestock manure pollution is the main cause of gastrointestinal diseases in domestic farmers for many years (Delahoy et al., 2018).

However, livestock manure is not all bad. Relevant studies have shown that organic matter, nitrogen, phosphorus, potassium, and other components rich in livestock manure can not only provide nutrients needed for crop growth but also generate a large amount of electricity and gas energy through biogas and other projects (Holm-Nielsen et al., 2009; Ramos-Suárez et al., 2019; Li J. et al., 2021). It can be seen that strengthening the resource utilization of livestock manure is of great significance to the high-quality development of the ecological environment and the sustainable development of agriculture. The Chinese government attaches great importance to the resource utilization of livestock manure and has issued a series of policy notices, such as "On Further Clarifying the Requirements for Returning Livestock manure to the Field and Strengthening Supervision of Livestock manure Pollution" and "Opinions on Promoting the Resource Utilization of Livestock manure," to accelerate the resource utilization of livestock manure. According to statistics from the Ministry of Agriculture and Rural Affairs of China, the utilization rate of livestock manure resources in China reached 75% in 2020 (Website of the Ministry of Agriculture and Rural Affairs, 2020). However, as the world's largest livestock producer, with an annual output of 3.8 billion tons of livestock manure, China still faces great ecological and environmental pressure. The Chinese government aims to use 80% of livestock manure by 2025. Therefore, there is still a long way to go to continuously promote the utilization rate of livestock manure resources.

As the main body of livestock manure resource utilization, the behavioral intention of farmers will directly affect the progress of livestock manure resource utilization. There have been many studies on the willingness or behavior of livestock manure resource utilization by farmers in academia, which can be roughly divided into three aspects: individual and family characteristics, Social economic factors, and subjective cognition. In terms of individual and family characteristics of farmers, the age, gender, educational background, breeding scale, and labor input of farmers will be the influencing factors of the response of livestock manure recycling behavior (Materechera, 2010; Gebrezgabher et al., 2015; Zhang and Xiao, 2016; Case et al., 2017). In terms of social and economic factors, government subsidies, social norms, whether to join cooperatives, environmental rules, and policies are all influencing factors in the response of livestock manure recycling behavior (Roubík et al., 2018; Li and Wang, 2019; Bulent gurbuz and Ozkan, 2021; Wang et al., 2021; Yao and Zhang, 2021; Yue et al., 2022). In terms of subjective cognition, value cognition, environmental knowledge, health belief, and so on will be the influencing factors of the behavioral response to the recycling of livestock manure (Afroz et al., 2009; Li and Wang, 2022; Yazdanpanah et al., 2022a; Zhang et al., 2022a).

The existing results have important reference significance and theoretical value for the research on the resource utilization behavior of livestock manure, but there are still some defects. Firstly, the behavior of livestock manure recycling is a decision-making process from intention initiation to behavior response. Secondly, the resource utilization of livestock manure has a high value, but whether the theoretical value can be truly transformed into the actual value will largely depend on the psychological perception of farmers. According to the theory of farmer behavior, perceived value is the most direct factor affecting individual willingness (Yazdanpanah et al., 2022a). The perceived value judgment of farmers will greatly affect their behavior of recycling livestock and poultry manure. Thirdly, with the development of economic diversification and rural modernization in China, the multiple occupations of farmers are more common. The concurrent operation of farmers will inevitably affect their choice of production mode and allocation of production factors (Zhong et al., 2016). The resource utilization of livestock manure is a process that requires long-term labor time and production factors. Therefore, different types of concurrent business may lead to different perceived values of livestock manure resource utilization behaviors by farmers, which will lead to different utilization behaviors. In the existing literature, farmers are assumed to be homogeneous groups with uniform behavior, ignoring the heterogeneity of the concurrent business.

To fill the above defects in the existing research and further enrich the relevant literature on the resource utilization of livestock manure, the innovation and marginal contribution of this paper are mainly reflected in the following aspects: Firstly, it takes the lead in introducing the theoretical basis of perceived value into the research, to explore how the perceived value drives farmers' behavior of recycling livestock manure. Secondly, the decision-making process from intention initiation to behavioral response was connected in the study, and the decision-making mechanism of resource utilization of livestock manure was deeply explored. Thirdly, the multi-group structural equation is used in the study to explore the driving differences of perceived value theory in the process of livestock manure resource utilization among farmers with different types of concurrent businesses.

Finally, the research goal of this study is to provide scientific and effective policy and theoretical support for policymakers from the perspective of farmers' psychological perception through field investigation and empirical analysis of the sample areas.

The structure of the remaining part of this paper is as follows: the second part analyzes the applied theory and puts forward the research hypothesis; The third part explains the selected data, variables, and models. The fourth part uses the model to analyze and discuss the data. The fifth part summarizes the research conclusions, puts forward policy suggestions, and expounds on the limitations of this research.

2. Theoretical analysis and research hypothesis

2.1. Theoretical analysis

The theoretical model of perceived value was first proposed by Zeithaml in 1988 and should be used in the study of consumer behavior (Zeithaml, 1988). Perceived value refers to the overall evaluation of the behavior subject after comparing and weighing the perceived benefits and perceived risks brought by the behavior. After the behavioral subject perceives the perceived benefit as higher than the perceived risk, the overall perceived value level will be at a higher level, and then make the behavioral tendency more obvious. In essence, it is a refinement of the individual cognition of the actor (Sweeney and Soutar, 2001). In the existing research results, the theory of perceived value satisfies the path paradigm and logical mechanism of "cognitive level → cognitive trade-off → perceived value → behavioral intention → behavioral response" (Woodruff, 1997). This logical paradigm shows that individuals weigh the benefits and losses of their behaviors under the influence of self-cognition, to generate the self-perceived value of comprehensive evaluation to influence the individual's behavioral willingness, and finally give rise to the individual's behavioral response. Previous studies have proved that the perceived value theory has strong applicability in the research directions of farmers' homestead withdrawal, farmers' land input, green agricultural production, and farmers' farmland protection (Ren et al., 2018; Hu et al., 2020; Li and

Chen, 2020; Wang et al., 2022). The resource utilization behavior of livestock manure is a kind of agricultural subject behavior, which is essentially the result of the balance between the benefits and risks of the resource utilization of manure, and its path also satisfies the paradigm from cognition to behavior. In conclusion, this paper constructed a behavioral decision-making model for livestock manure resource utilization (Figure 1).

2.2. Research hypothesis

Perceived value includes perceived benefits and perceived risks. Perceived benefits refer to the amount of income that the subject perceives in the process of behavior, which has a positive impact on individual behavioral cognition (Tsujikawa et al., 2016). Perceived benefit has a positive effect on perceived value, that is, the higher the perceived benefit, the higher the perceived value. In this study, the benefits perceived by farmers can be divided into three dimensions: economic, social, and ecological. Farmers have higher perceived benefits when they perceive that the resource utilization of livestock manure can bring higher economic benefits or reduce part of production and breeding costs, reduce environmental pollution and disease transmission, and promote the construction of new countryside and the development of ecological civilization. Perceived risk refers to the subject's negative perception of possible uncertain events in the process of behavior (Jacobs and Worthley, 1999), which has a significant negative impact on individual cognition (Leiserowitz, 2006). Perceived risk has a reverse effect on perceived value, that is, the higher the perceived risk, the lower the perceived value. In this study, the risks perceived by farmers can be divided into three dimensions: economy, technology, and policy. Farmers have higher perceived risks when they perceive that the resource utilization of livestock manure will involve more economic costs, require complex technical knowledge, and obtain low policy support and restrictions. The overall perceived value of farmers is the result of perceived benefits and perceived risks.

Behavioral intention refers to the psychological intention of the subject before the behavior. Theoretically, if the farmers hold a high perceived value for the resource utilization of livestock manure, it will stimulate their psychological intention to resource utilization of livestock manure and improve their behavioral intention. Utilization behavior refers to the input degree of the actor to the implementation of a behavior. Theoretically, the stronger the behavioral willingness of livestock manure resource utilization, the more likely it is for farmers to put their will into action, to improve the input intensity of farmers. To sum up, this paper makes the following assumptions:

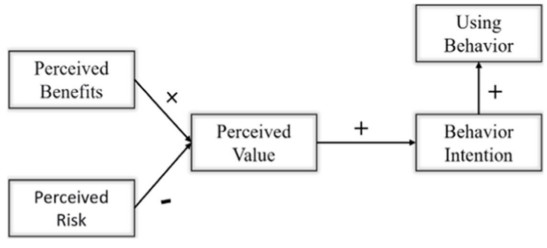

FIGURE 1
Theoretical analysis framework.

H1: Perceived revenue has a positive driving effect on perceived value.

H2: Perceived risk has a reverse driving effect on perceived value.

H3: Perceived value has a positive driving effect on behavioral intention.

H4: Behavioral intention has a positive driving effect on using behavior.

3. Data, variables, and model

3.1. Data sources

The data in this study came from the field survey conducted by the research team in rural areas of Shandong Province from July to August 2022. The animal husbandry system in Shandong Province is complete and large scale. The annual production of poultry meat accounts for 1/6 of that in China, and the total production of meat, eggs and milk have been the first in China since 1992 (China Shandong, 2021)As a big breeding province in China, the annual output of livestock manure in Shandong Province also ranks among the top in China. The huge output of livestock manure not only becomes an important and difficult problem for rural human settlement environment improvement but also restricts the sustainable development of animal husbandry in Shandong Province. Therefore, the survey data based on Shandong Province are sufficiently representative and referential, which can meet the research needs of this paper.

Our conduct research is divided into two categories, pre-survey and formal research, pre-survey is conducted by face-to-face interviews, and formal research is conducted by a combination of interviews and questionnaires. The pre-survey was conducted by face-to-face interviews with 20 randomly selected farmers in Jining City to get a preliminary understanding of the resource utilization of livestock and poultry manure by farmers, and the questionnaire was modified and improved according to the feedback results. In order to ensure that the sample was representative and could represent the overall population, the formal research used a combination of stratified sampling and random sampling. Firstly, five cities with large annual farming output in Shandong Province, Jining, Tai'an, Dezhou, Binzhou, and Dongying were selected, then two counties were randomly selected in each city, then 1–3 townships were randomly selected from each county, and finally the farmers to fill in the questionnaire were randomly selected and screened in these townships (Figure 2). Before conducting questionnaire research in each sampling area, the survey team first conducted face-to-face interviews with individual demonstration farmers under the leadership of local animal husbandry bureau staff, in order to understand the main local farming species and their manure treatment methods, etc., so that the subsequent questionnaire survey of other local farmers could be carried out smoothly. Pre-survey and interviews with demonstration farmers in each area took the same interview procedure steps. Interviews were conducted with the main person in charge of the farm and in most cases one or more family members or staff. The location of the interviews was chosen at the farm. The purpose of the interview was to ease the tension at the beginning of the interview, to reduce the pressure on the respondents to answer, and to make them feel comfortable so that the interview could be conducted properly and more detailed and realistic information could be obtained. The duration of the interviews ranged from 1 to 2 h. Through the interviews with the interviewees, we got a deeper understanding of the farmers' personal and family situation and the real situation of perceived value. This provided a great help for the subsequent questionnaire research.

After interviewing the local model farmers, we conducted questionnaire research on other local farmers. Since face-to-face research can "reduce the response bias and improve the response rate" (Lou et al., 2021), we conducted face-to-face research at the farms or homes of the farmers. In the study, we first asked simple questions to the farmers, and those who answered the questions carefully were given a questionnaire to fill in. Before filling out the questionnaire, we declared to the farmers that their data would be kept confidential and they could choose voluntarily whether to fill out the questionnaire or not. Due to the low educational level of some farmers, we dictated the questions to those farmers who could not read or had difficulty in reading, without any bias guidance during the dictation process. The response time for each questionnaire was about 15 to 25 min. Finally, a total of 340 questionnaires were distributed and 340 were collected, of which 307 were valid and 33 were invalid, with an effective rate of 90.3%.

The distribution of individual characteristics of the sample is shown in Table 1. In terms of gender, men accounted for 80.8%, much higher than women who accounted for 19.2%, which may be due to the fact that livestock farming requires high-intensity physical labor, and men's physical strength is higher than that of women. In terms of age group, 31.6% of the sample were under 44 years old, 52.8% were 44–59 years old, and 15.6% were over 60 years old, with a higher percentage of middle-aged and elderly people. There are two possible reasons for this, one is that young people go out to work, and during the survey, we found that the number of young people in the villages is significantly less than the number in the cities; the second is the result of increased aging, and China is currently in an aging stage. The education level of farmers is 76.5% in junior high school and below, and 23.5% in high school and above, which indicates that the education level of farmers is not high. The proportion of labor input 1–3 people is 70.36%, the proportion of input 4–7 people is 27.69%, and the proportion of input more than 7 people is 1.95%, which indicates that most of the farmers are mainly family farming.

3.2. Variable definition

3.2.1. Behavior of resource utilization of livestock manure

Referring to the research of Ren and Zhong (2022) and Boz (2016), the utilization decision and utilization intensity were used to characterize the resource utilization behavior of livestock manure of farmers. Since the most direct form of resource utilization behavior of farmers is "yes" and "no," the utilization decision adopts the binary assignment method. If the farmer has carried out the resource utilization of livestock manure, the value is 1, if not, the value is 0. Utilization intensity refers to the number of years for livestock manure resource utilization.

3.2.2. Behavioral intention of livestock manure recycling

Referring to the research of Li Q. et al. (2021), Li (2012), and other scholars, the behavioral intention of livestock manure recycling was characterized by three aspects: Recommendation intention, utilization intention, and investment intention. All items were measured on a 5-point Likert scale. The answer options were "very low," "low," "general," "high," and "very high," with the values of "1–5," respectively.

3.2.3. Perceived value of livestock manure resources

Referring to the research of Li et al. (2020), Ren et al. (2018), and other scholars, the perceived value of livestock manure resources was characterized by three aspects: Value cognition, behavior attitude, and recommendation cognition. All items were measured on a 5-point Likert scale. The answer options were "very low," "low," "general," "high," and "very high," with the values of "1–5," respectively.

3.2.4. Perceived risk of livestock manure resource utilization

Referring to the research of Wang et al. (2022) and Jin et al. (2022), the perceived risks of livestock manure recycling were characterized by three aspects: economic risk, technical risk, and policy risk. All the items were measured on a 5-point Likert scale, and the answer options were "completely disagree," "disagree," "basically agree," "relatively agree," and "completely agree," with the values of "1–5," respectively.

3.2.5. Perceived benefits of livestock manure resource utilization

Referring to the research of Wang et al. (2019) and Li et al. (2020), the perceived value of livestock manure resource utilization was characterized by three aspects: economic benefits, ecological benefits, and social benefits. All the items were measured on a 5-point Likert scale, and the answer options were "completely disagree," "disagree," "basically agree," "relatively agree," and "completely agree," with the values of "1–5," respectively (Table 2).

3.3. Model construction

In the setting of this study, variables such as perceived benefits, perceived risks, and perceived values are all latent variables and their degrees are difficult to directly observe. Structural Equation Model (SEM), also known as latent variable model, is a statistical method using linear equation system to express the relationship between observed variables and latent variables, as well as between latent variables and is

TABLE 1 Main characteristics of the sample.

Type	Option	Quantity	Proportion	Type	Option	Quantity	Proportion
Sex	Male	248	80.8	Education level	Primary school and below	235	76.5
	Female	59	19.2		Junior high school and above	72	23.5
Age	Under 44	97	31.6	Labor input	1–3	216	70.4
	45–59	162	52.8		4–7	85	27.7
	Over 59	48	15.6		Over 7	6	1.9

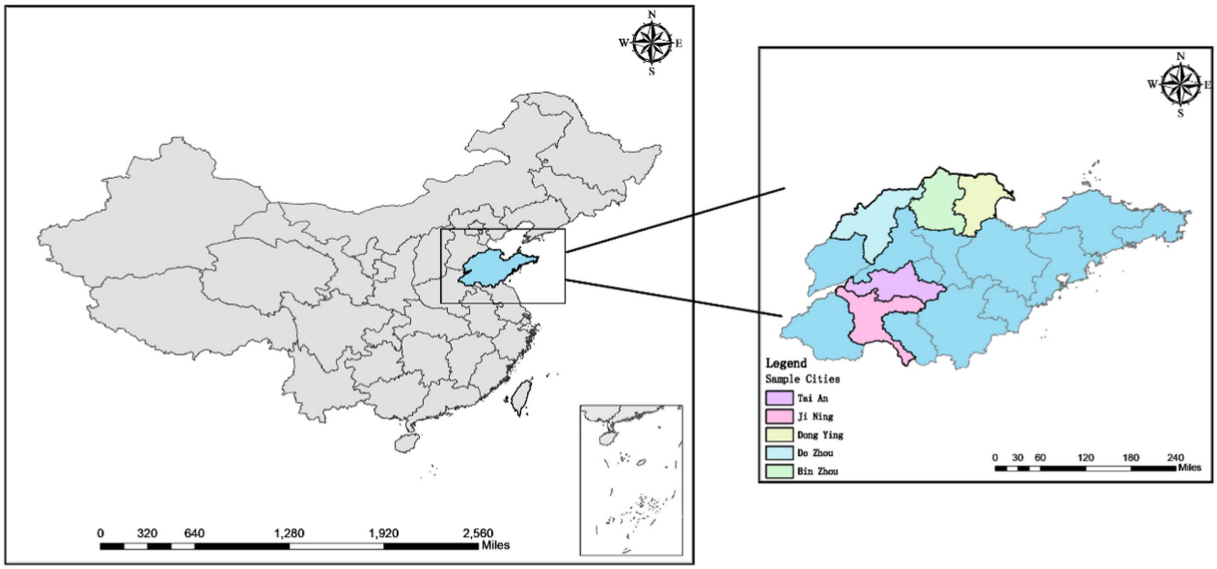

FIGURE 2
Survey region.

widely used in psychology and social sciences. It has the advantage of not only its strong adaptability to the measurement of latent variables, but also its ability to deal with multiple dependent variables at the same time, estimate factor structure and factor relationship, and better reveal the relationship between variables. Structural equation model can be combined with theoretical model to meet the requirements of scholars, such as Theory of Planned Behavior (Yazdanpanah et al., 2022b), Theory of Reasoned Action (Senger et al., 2017), Theory of Perceived Value (Li et al., 2020), etc. In addition, there are many literatures using SEM to conduct researches on farmers. Therefore, this paper combines structural equation model with perceived value theory to study. The equation is expressed as follows:

$$\eta = B\eta + \Gamma\xi + \zeta \quad (1)$$

$$Y = \Lambda y\eta + \varepsilon \quad (2)$$

$$X = \Lambda x\xi + \delta \quad (3)$$

Equation (1) is the structural equation, η is the endogenous latent variable; B is the coefficient of endogenous latent variable η. ξ is an exogenous latent variable; Γ is the coefficient of the exogenous latent variable ξ. ζ is the residual. Equations (2) and (3) are measurement equations, Y and X are observed variable vectors of endogenous latent variable η and exogenous latent variable ξ, respectively. Λy and Λx represent the correlation coefficient matrix of Y on η and X on ξ, respectively. Both ε and δ represent measurement errors.

Considering the heterogeneity of concurrent business among farmers, this paper uses the type of concurrent business of farmers as the moderating variable to conduct a multi-group analysis, which can better test the driving effects of perceived value on the resource utilization behavior of livestock and poultry waste of different concurrent business types of farmers. Multi-group SEM analysis is to evaluate whether the model adapted to a certain text is also adapted to other different sample groups, that is, to evaluate whether the hypothetical model proposed by the researcher is equal between different samples or whether the parameters have invariability (Cui and Li, 2018). Based on Li and Zhao's (2017) classification standard for the type of concurrent business, this paper made adjustments according to the actual investigation situation, and divided the farmers into two types: full-time farming and combined farming, so as to facilitate the multi-group SEM analysis. Among them, full-time farming refers to the farmers whose main income of livestock and poultry farming accounts for 80% or more of the total income, and the combination type refers to the farmers whose family livestock and poultry farming account for less than 80% of the family income. In the survey, the proportion of combined cultivation and full-time cultivation was 71.7% and 28.3%, respectively.

4. Data analysis and discussion

4.1. Reliability and validity test

To ensure the validity and credibility of the research data, SPSS26.0 was used to test the overall reliability and validity of the questionnaire and the reliability and validity of each latent variable, respectively. The test results showed that the Cronbach's α value of the overall reliability of the questionnaire was 0.786, and the Cronbach's α values of PB, PR, PV, BI, and BR were 0.720, 0.635, 0.788, 0.756, and 0.608, respectively, which were all higher than the standard value 0.6. The KMO value of the overall validity of the questionnaire was 0.837, which was higher than the benchmark value of 0.7, and the KMO value of each latent variable was also higher than the benchmark value of 0.5, indicating that the data had good reliability and validity. In addition, Harman univariate test technique was used to conduct principal component analysis to test the common method bias. Principal component analysis was carried out for each item. It was found that the characteristic root of three factors was greater than 1, and the variance explanation rate of the first common factor was 35.7% < 40%. According to the indexes of the Harman univariate test results, there is no serious common method bias effect

TABLE 2 Variable definition and measurement items.

Variable	Index	Measurement items	Standard deviation
Using behavior (UB)	Using decision	Whether the fecal waste resources have been used (UB_1)	0.367
	Using intensity	The number of years of continuous fecal recycling (UB_2)	1.277
Behavior intention (BI)	Recommendation intention	Willing to recommend to others the degree of resource utilization of livestock manure (BI_1)	0.935
	Utilization intention	The degree of willingness to recycle livestock manure (BI_2)	0.981
	Investment intention	Willing to invest a certain amount of money, time, labor and other costs in the process of recycling livestock manure (BI_3)	1.075
Perceived value (PV)	Behavior attitude	Positive attitude toward resource utilization of livestock manure (PV_1)	0.940
	Value cognition	It is believed that the resource utilization of livestock manure can bring certain benefits (PV_2)	0.912
	Significance cognition	It is considered that the resource utilization of livestock manure has positive significance (PV_3)	0.922
Perceived risk (PR)	Economic risk	Concerned about the excessive labor, time, and money involved in the processing process (PR_1)	0.815
	Technical risk	Concerned about not being able to master the required knowledge and techniques (PR_2)	0.823
	Policy risk	Concerned that the government's relevant policy formulation and implementation is not in place (PR_3)	0.852
Perceived benefits (PB)	Economic benefits	Can reduce breeding cost, raise income level (PB_1)	0.998
	Ecological benefits	Can reduce the spread of disease and protect the ecological environment (PB_2)	0.958
	Social benefits	Can promote ecological progress and the development of a new countryside (PB_3)	0.954

among the variables. The results were within the acceptable range (Shiau and Luo, 2012). The specific convergent validity information of the experimental data is shown in Table 3.

4.2. Model fitness test

In order to judge the degree of fit between the research reality and the null hypothesis, AMOS23.0 software was used to test the fitness of the theoretical model. The test results show that the model has good significance and meets the adaptation standard, and has a good model fitness. The detailed data are shown in Table 4.

4.3. Structural equation model estimation result

After the model calculation, it was found that the livestock manure resource utilization behavior of farmers followed the logic of "cognitive level → cognitive trade-off → perceived value → behavioral intention → behavioral performance." All hypotheses H1–H4 above hold. As shown in Figure 3 (*$p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, PB, Perceived benefits; PR, Perceived risk; PV, Perceived value; BI, Behavioral intention; UB, Using behavior).

4.3.1. Perceived benefits

Perceived benefit has a positive driving effect on perceived value, and its path coefficient is 0.66, which is larger than that of perceived risk, indicating that its driving effect on perceived value is more obvious. Among the three observed variables of perceived benefits, the path coefficients of economic benefits, ecological benefits, and social benefits are 0.62, 0.74, and 0.70, respectively, which indicates that ecological benefits have the greatest impact on the perceived benefits of farmers. This is consistent with the conclusion proved by Bin et al. that "farmers show strong positive awareness of the ecological benefits of positive externalities" (Bin et al., 2017). According to the principle of rational economic man hypothesis, economic benefit should be the factor that has the greatest impact on perceived benefit. But in the survey found that due to the livestock manure resource utilization system is not perfect, their use or resources into the sale of income is not high, most farmers can only be reached after livestock manure recycling use or a slight surplus of balance of payments, but after waste resource recovery of ecological environment, quality and public health improvement is more apparent.

4.3.2. Perceived risk

Perceived risk has a reverse driving effect on perceived value, and its path coefficient is −0.23. Among the three observed variables of perceived risk, the path coefficients of economic risk, technical risk, and policy risk are 0.66, 0.60, and 0.56, respectively, and the path coefficient of economic risk is the largest, which indicates that economic risk has the greatest influence on farmers' perceived risk. This is consistent with the conclusion confirmed by Lin et al. that "economic affordability is the most important factor for farmers to consider when polluting livestock manure (Lin et al., 2018). It is found that due to the frequent occurrence of animal diseases in recent years, the risk of livestock and poultry breeding is large, and

TABLE 3 Convergent validity table.

Variables	Items	Significance estimation			Reliability of questions		Component reliability	Convergent validity
		S.E.	*z*-value	*P*	Std.	SMC	CR	AVE
Perceived benefits	PB_1				0.616	0.379	0.727	0.472
	PB_2	0.131	8.831	***	0.739	0.546		
	PB_3	0.126	8.658	***	0.7	0.49		
Perceived risk	PR_1				0.661	0.437	0.636	0.369
	PR_2	0.151	6.075	***	0.599	0.359		
	PR_3	0.147	6.012	***	0.558	0.311		
Perceived value	PV_1				0.709	0.503	0.78	0.543
	PV_2	0.09	10.507	***	0.69	0.476		
	PV_3	0.095	11.716	***	0.807	0.651		
Behavior intention	BI_1				0.635	0.403	0.734	0.481
	BI_2	0.126	9.876	***	0.756	0.572		
	BI_3	0.133	9.295	***	0.684	0.468		
Using behavior	BR_1				0.874	0.764	0.895	0.81
	BR_2	0.223	16.548	***	0.925	0.856		

***$p < 0.01$.

TABLE 4 Fitting results of model fitness.

Goodness-of-fit index	Absolute fit index				Value-added compatibility indicators			Simple fit index		
	χ2/df	GFI	AGFI	RMSEA	TLI	CFI	IFI	PNFI	PCFI	PGFI
Criteria	<3	>0.9	>0.8	<0.08	>0.8	>0.9	>0.9	>0.5	>0.5	>0.5
Modified fitting effect	2.897	0.917	0.879	0.079	0.889	0.912	0.913	0.691	0.722	0.629

the cost of all kinds of breeding is high. In addition, the process of resource utilization of livestock manure requires a lot of labor, time, capital and other inputs. Farmers will be concerned about the various costs generated by the resource utilization of livestock manure. And affected by the total number of farmers with the combination of breeding and breeding, a large number of farmers not only have to carry out livestock breeding but also have to carry out agricultural production, so the impact of farmers on labor and time investment is also at a low level.

4.3.3. Perceived value

Perceived value has a positive driving effect on behavioral intention, and its path coefficient is 0.63. Among the three observed variables of perceived value, the path coefficients of behavior attitude, value cognition, and meaning cognition are 0.71, 0.69, and 0.81, respectively, and the path coefficient of perceived meaning cognition is the largest, which indicates that meaning cognition has the greatest influence on perceived value. This is consistent with the conclusion confirmed by Li et al. (2020). Found in the field survey, policy propaganda focuses on livestock manure recycling behavior in environmental protection, public health, and the importance of social construction. In addition, the supervision and regulation of village cadres in the implementation process gives farmers a sense of urgency, which leads to a higher cognition of the significance of the livestock manure resource utilization, but a lower cognition of value.

4.3.4. Behavioral intention

Behavioral intention had a positive effect on utilization behavior, and the path coefficient was 0.75. The stronger the willingness of farmers to utilize livestock manure pollution resources, the more likely the utilization behavior was. Among the three observed variables of behavioral intention, the path coefficients of promotion intention, utilization intention, and investment intention were 0.64, 0.76, and 0.68, respectively, and the path coefficient of utilization intention was the highest, which indicated that the overall farmers still had a relatively positive attitude toward the resource utilization of livestock manure, and were willing to try and participate in it. But relatively speaking, farmers are not willing to invest too much economic, time, and labor costs.

4.4. Multi-group model test

In multi-group analysis, various parameter restrictions are needed to find out the most suitable path model (Lee and Whittaker, 2021). After comparing the adaptation indexes of the baseline model (i.e., the unconstrained model), the measurement weights model, the structural weights model, the structural covariances model, the structural residuals

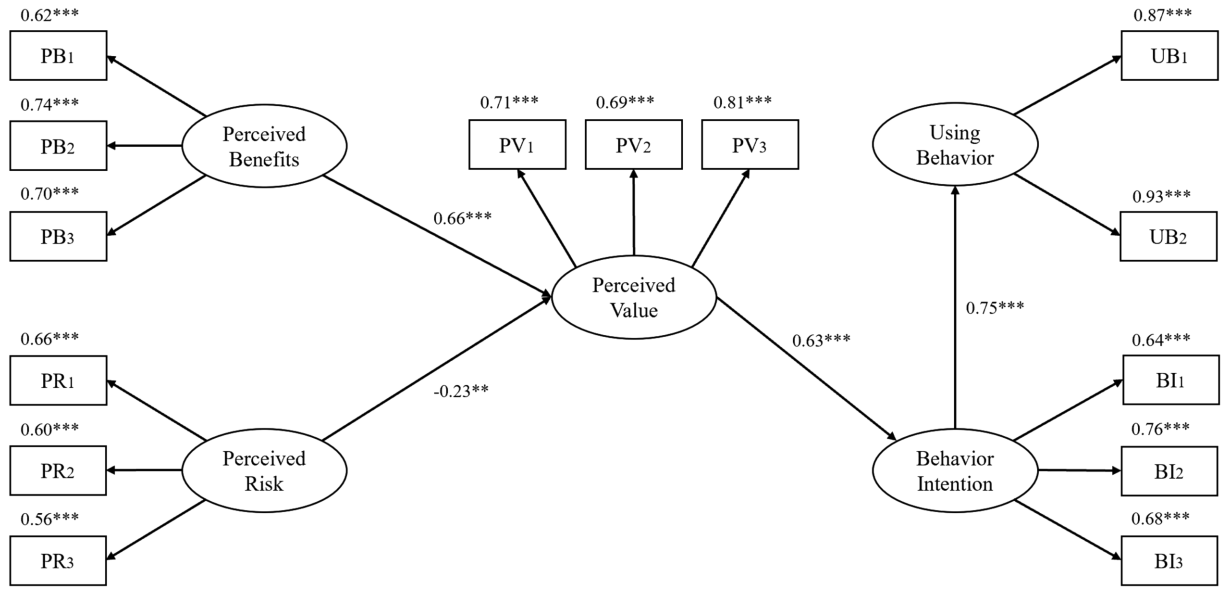

FIGURE 3
Structural equation model and standardized path coefficient diagram. **p<0.05; ***p<0.01; PB, Perceived Benefits; PR, Perceived Risk; PV, Perceived Value; UB, Using Behavior; BI, Behavior Intention.

model, and the measurement residuals model. The measurement weights model is finally selected as the multi-group analysis model in this paper, and the results are shown in Table 5.

The invariance test was carried out after the indexes of each model were well-matched. Comparing the five models with the baseline model, the results in Table 6 show that ΔP is less than 0.05, indicating that there are significant differences in the corresponding sample models of different project types (Zhang et al., 2022b).

As shown in Table 7, many groups of samples are similar to the results of the analysis of the whole samples: the perceived benefits and perceived risk to the perceived value and perceived value to the behavior intention and behavior intention of using action behavior have a significant role in driving in the path, and the direction the same as the whole sample analysis, hypothesis H1–H4 in different types of farmers has been proved again. However, there are some differences, mainly showing that the driving strength of perceived benefit and perceived risk to perceived value is significantly different for different farmer types. In the full-time farming group, the driving effect of perceived benefit on perceived value, the driving effect of perceived risk on perceived value, the driving effect of perceived value on behavioral intention, and the driving effect of behavioral intention on utilization behavior were stronger than those in the group of combination planting and breeding. This is consistent with the previous conclusion obtained by Zhang et al. (2022b). The possible reason is that full-time farmers have a higher degree of farming specialization and are less dependent on land production. The survey found that in the process of livestock manure recycling use full-time farmers' investment of capital, technology and equipment is more, by using the process toward large scale, and most full-time farmers farming scale is larger, the government subsidy and support degree is bigger, the results of that waste recycling use have a good sale and use of a way out. On the contrary, the farmers of the combination type have a weak perception of technology access, policy subsidies, and significance value, which may lead to a low behavioral intention of the combination type farmers.

5. Conclusion

5.1. Conclusion

Based on the survey data of farmers in Shandong Province of China in 2022, the multi-group structural equation model was used to empirically analyze the driving mechanism of perceived value on livestock manure resource utilization behavior of farmers. The following conclusions are obtained:

(1) Livestock manure resource utilization behavior of farmers follows the logic of "cognitive level → cognitive trade-off → perceived value → behavioral intention → behavioral performance." It shows that perceived benefit and perceived risk have positive and reverse driving effects on perceived value, respectively. Perceived value has an obvious positive driving effect on behavioral intention. The behavioral intention has an obvious positive driving effect on utilization behavior.
(2) Among the observed variables of perceived benefits, ecological benefits have the greatest impact; Among the observed variables of perceived risk, economic risk has the greatest influence. Among the observed variables of perceived value, meaning cognition has the greatest influence. Among the observed variables of behavioral intention, intention to utilize has the greatest influence.
(3) Perceived value had differentiated effects on livestock manure resource utilization behavior of different part-time farmers, and its driving effect on full-time farmers was more obvious.

5.2. Policy recommendations

Based on the above research conclusions, the following policy recommendations are put forward:

TABLE 5 Multi-group analysis adaptation results.

Model	CMIN	DF	*P*	CMIN/DF	CFI	RMSEA	AIC	ECVI	PCFI
Unconstrained	267.135	144	0	1.855	0.906	0.053	399.135	1.309	0.717
Measurement weights	284.484	153	0	1.859	0.899	0.053	398.484	1.307	0.756
Structural weights	313.719	157	0	1.998	0.88	0.057	419.719	1.376	0.759
Structural covariances	333.081	160	0	2.082	0.868	0.06	433.081	1.42	0.763
Structural residuals	376.59	163	0	2.31	0.837	0.066	470.59	1.543	0.749
Measurement residuals	407.812	177	0	2.304	0.823	0.065	473.812	1.553	0.801

TABLE 6 Results of the invariance test.

Model	Delta-CMIN	Delta-DF	Delta-P	Delta-CMIN/DF	Delta-CFI	Delta-RMSEA	Delta-AIC	Delta-ECVI	Delta-PCFI
Measurement weights	17.349	9	0.044	0.004	−0.007	0	−0.651	−0.002	0.039
Structural weights	46.584	13	0.000	0.143	−0.026	0.004	20.584	0.067	0.042
Structural covariances	65.946	16	0.000	0.227	−0.038	0.007	33.946	0.111	0.046
Structural residuals	109.455	19	0.000	0.455	−0.069	0.013	71.455	0.234	0.032
Measurement residuals	140.677	33	0.000	0.449	−0.083	0.012	74.677	0.244	0.084

TABLE 7 The result of Multi-group model test.

Affect the path	Full-time farming	Combination cultivation and breeding
Perceived value ← perceived benefits	0.817***	0.404***
Perceived value ← perceived risk	−0.380**	−0.226**
Behavioral intention ← perceived value	0.716***	0.366***
Using behavior ← behavioral intention	0.713***	0.632***

**$p < 0.05$.
***$p < 0.01$.

(1) Since perceived income and perceived risk have significant positive and negative driving effects on perceived value, respectively, and economic income has the lowest impact on perceived income, while economic risk has the largest impact on perceived risk, it is necessary to improve the resource utilization system of livestock manure so that the products of livestock and poultry manure resource utilization can have a better realization channel, to solve the situation that the income and expenditure of livestock and poultry manure resource utilization by farmers offset or have a slight surplus; We should strengthen the investment in science and technology, reduce the operating cost of technical facilities, and achieve the goal of reducing the high investment in the economy, time, and labor in the use of farmers; Formulate incentive and subsidy policies, improve industry operation laws and regulations, to improve the perceived value of farmers in general.

(2) Since perceived value has a significant positive driving effect on behavioral will, behavioral will has a significant positive driving effect on utilization behavior, value cognition has the least impact on perceived value, and recommendation intention has the least impact on behavioral will, we should make full use of various information dissemination drivers to increase the significance and value publicity of livestock and poultry manure recycling. In the process of publicity, attention should be paid to the multi-dimensional development, not only to enable farmers to realize the significance and value of resource utilization of livestock and poultry manure to society but also to make them feel the significance and value of resource utilization to themselves, to improve the sense of identity and acquisition of farmers.

(3) Since perceived value has a stronger driving effect on full-time farmers and a weaker driving effect on the combination of planting and farming farmers, the promotion of livestock manure resource utilization needs to be "classified and implemented." For the combination type farmers, policy subsidies should be increased and the access threshold of technology and equipment should be reduced. Full-time farmers, can be encouraged to actively try new treatment

methods to promote more convenient and effective livestock manure resource production.

5.3. Research limitations and prospects

Finally, it should be pointed out that this study still has some limitations. (1) Survey region: in this paper, the data of farmers in Shandong, China, are used, so the sample coverage is small and the survey area is narrow. Due to the in-depth economic diversification and regional development differences and other factors, it is necessary to try to further verify and analyze the data of farmers at the national level or in areas with obvious economic development degrees. (2) The division of the types of farmers' part-time jobs: in this paper, the types of part-time farmers are directly divided into two types: the combination of planting and farming and full-time farmers, and the degree of fineness of division still needs to be improved. Future studies can classify the types of farmers according to more detailed standards, to study the differences in the resource utilization behavior of livestock manure pollution of different types of farmers. (3) The data in this study are from cross-sectional data, which cannot investigate the long-term dynamic change process of farmers' resource utilization behavior. In the future, time series data should be established to conduct a more comprehensive and systematic analysis of farmers' resource utilization behavior.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Shandong Normal University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

RG and GL built the conceptual model of the paper and analyzed the data. XW and YF conducted field investigations and collected data. RG wrote the paper. ZR put forward the idea of writing the paper and carried on the guidance and revision to the paper. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

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The impact of continuous use intention of cooperative members on new agricultural technologies

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The widespread application of new agricultural technologies promotes an increase in agricultural production and income and in the optimization and adjustment of the industrial structure. However, there are problems such as low promotion efficiency, an insufficient transformation of achievements, and a mismatch of supply and demand in the process of promotion. Based on the research context of farmer cooperatives in China, this study explores the factors influencing the continuous use intention of cooperative members toward new agricultural technologies and builds a research structure based on the unified theory of acceptance and use of technology (UTAUT) model, which includes performance expectations, effort expectations, cooperative social impact, and policy support. A total of 401 valid questionnaires were collected, and the data were analyzed in three stages using descriptive statistics, a measurement validation model, and a structural equation model, using a survey questionnaire and by inviting members of farmer cooperatives within China to participate in an online survey through a web-based electronic questionnaire. The results of the study found that policy support plays a dominant role in the intention of cooperative members of farmers to use new agricultural technologies consistently, and cooperative social impact plays a facilitating role, while factors such as performance expectation and effort expectation also have a significantly positive effect on the intention to use consistently.

KEYWORDS

farmers' cooperatives, new agricultural technology, unified theory of acceptance and use of technology, continuous use intention, social impact of cooperatives, policy support

1. Introduction

China is a large agricultural country. Agricultural development is the fundamental basis for national stability and sustainable social development. Therefore, the Chinese government pays great attention to three rural issues. Agriculture, rural areas, and farmers are three issues related to rural development in mainland China. The implementation of the agricultural revitalization strategy would promote the modernization of agriculture and improve the sense of access, happiness, and security of farmers. According to the endogenous growth theory, the progress of agricultural science and technology is at the core of the development of modern agriculture and the construction of agricultural modernization (Mao et al., 2013). The Central Committee of the Chinese Communist Party has issued a series of "Central No. 1" documents. The focus is on agricultural science and technology. The basic national policy of agricultural development is to continuously increase the progress and innovation of agricultural science and technology. It includes the promotion of new technologies such as biotechnology, information technology, gene technology, and genetic breeding. The wide application in agricultural production has greatly promoted the development of agriculture in terms of intelligence and information technology.

According to the classification standard of the World Bank, small farmers are defined as those with an arable land area of 30 acres or less. Based on the data of the third agricultural census, small farmers account for more than 98% of the main agricultural operators in China. Small farmers account for 90% of the agricultural workforce. The area of arable land operated by small farmers accounts for 70% of the total arable land area. Therefore, China's "big country and small farmers" remains the long-term basic national condition (Lu and Kong, 2019). It severely restricts the synergistic development of individual farmer production and mechanized operation, industrial development, and technical quality improvement. This has led to diminishing the marginal efficiency of production, weakened risk resistance, and reduced returns. Therefore, the contradiction between "small production" and "big market" is a common phenomenon (He, 2019). This leads to information asymmetry, homogeneous competition among farmers, weak sustainability of agricultural production, and disproportionate inputs and outputs.

Farmer cooperatives are an effective vehicle for developing moderate-scale agricultural operations and promoting agricultural development. They are also an important lever for the progress of agricultural science and technology. According to the statistics of the Ministry of Agriculture, by the end of April 2021, the number of farmer cooperatives registered nationwide reached 2.259 million, with more than 10,000 joint cooperatives, driving nearly 50% of farm households in China. Therefore, as the basis of rural revitalization in China and as an effective carrier of innovative rural science and technology service systems, the continued use of new agricultural technology by farmer cooperatives will certainly drive the promotion and application of certain technologies (Wang et al., 2020). In the process of promoting the application of new agricultural technologies, there still exists a shortage of funds for cooperatives, and the scale of operations is too small. This inhibits the demand for new agricultural technologies. The cognitive barriers and information asymmetry of farmers hinder the application of new agricultural technologies and cause other problems, resulting in a low adoption rate of new agricultural technologies.

At the same time, some scholars conducted studies based on the intention of individual farmers to use new agricultural technologies consistently. For example, Han et al. (2022) found that perceived usefulness, perceived ease of use, and external environment had significant effects on the continuous use intention of farmers toward the plant protection drones, and the literacy level of farmers played a moderating role in the continuous use intention toward the drones. Gao and Gu (2021) found that information quality has a significant impact on the intention to continuously use the WeChat agricultural science and technology public account, while service quality had an indirect impact on the intention to continuously use through satisfaction. Finally, in exploring the factors influencing the behavior of sustained use of soil testing by farmers of different scales, Li et al. (2018) found that sustained use behavior was directly influenced by the difference in scale, i.e., the highest percentage of use by farmers in the large-scale group. However, most of the existing studies on the success of information systems have focused on user perceptions and neglected to consider the factors influencing the intention of cooperative members to use new agricultural technologies consistently in the context of farmer cooperatives.

Therefore, this study examined the intention of Chinese farmer cooperative members to use new agricultural technologies consistently and the related influencing factors. Using the UTAUT model as a framework, the relationship between performance expectations, effort expectations, cooperative social impact, policy support, and continuous use intention is empirically demonstrated. The purpose of this study is to understand the factors that influence the intention to continuously use new agricultural technologies and to make relevant recommendations to government departments and farmer cooperatives in order to accelerate the application of new agricultural technologies in agricultural production.

2. Literature review

2.1. Farmer cooperatives

According to the Law of the People's Republic of China on Professional Farmers' Cooperatives issued in 2017, farmer cooperatives are based on the rural household joint production responsibility system: agricultural production operators or providers and utilizers of agricultural production and management services, voluntary association, and democratic management of mutual economic organizations. With the rapid development of farmer cooperatives, cooperatives play a "bridge" role in the process of agricultural science and technology promotion, effectively making up for the lack of supply of the agricultural science and technology promotion system of the government. In addition, cooperatives play a "leveraging role" between agricultural research institutes, public welfare extension agencies, and farmers, which is conducive to the balance between new agricultural technology research and the needs of farmers, thus promoting the application of new agricultural technologies (Yang and Li, 2020). The advantages of agricultural cooperatives are mainly reflected in (i) the purpose of serving cooperative members, which ensures that agricultural science and technology promotion is oriented to the needs of farmers; (ii) the membership system in which owners, promoters, and users are united, which ensures an effective match between agricultural science and technology promotion and the needs of farmers; and (iii) the service function of the unified purchase of agricultural materials and the unified sale of agricultural products, which effectively reduces the risk of new technologies (Yuan, 2017).

Therefore, farmer cooperatives in this study are organizations that are formed based on joint family production contracting, have the nature of economic entities, and are engaged in business activities such as production, processing, and marketing in the agricultural field.

2.2. Performance expectations, effort expectations, and continuous use intention

In the UTAUT model, performance expectation is the degree to which an individual believes that using a system or technology will help them improve job performance. Effort expectation is the level of effort an individual is expected to be willing to exert when

using a particular technique (Venkatesh et al., 2003). Continued use intention is the willingness of users to continue to use an information system after they have experienced it (Bhattacherjee, 2001). The research on the continued use intention is broadly based on the TAM model (Min et al., 2019), the ECM-ISC model (Tam et al., 2020), the D&M model (Shim and Jo, 2020), and the UTAUT model (Yuan et al., 2015). Scholars achieve rich results. Therefore, in this study, the continued use intention refers to the subjective willingness of members of farmer cooperatives to continue using the new agricultural technology after the initial use of the technology.

The UTAUT model has been commonly applied in diverse domains such as online learning (Li and Zhao, 2021), social media (Gruzd et al., 2012), e-government (Liang et al., 2015), and mobile Internet (Jiang et al., 2020) to understand factors related to the behavioral intention of users to use technology. In terms of empirical research on performance expectations on continuous use intention, Shen (2018) constructed a model of factors influencing the continuous use intention of VR video users based on the UTAUT model when studying the factors influencing the continuous use intention of VR video users combined with the functional characteristics of VR video. The empirical analysis found that performance expectations significantly and positively affect the continuous use intention of VR video users. While studying the factors influencing the continuous use intention toward mobile news apps in India, Cheng et al. (2020) found that performance expectations significantly and positively influence the continuous use intention of users. Finally, Tam et al. (2020), in their study of the factors influencing the intention to keep using mobile applications, constructed a model of the influence of the intention to keep using mobile applications based on the ECM model and the UTAUT2 model. They found through empirical analysis that performance expectations positively and significantly influence continued use intention.

In terms of empirical research on effort expectations on continuous use intention, Li and Zhao (2021) found through empirical analysis that effort expectations significantly and positively influenced the continuous use intention of students toward massive open online courses (MOOC). Liang et al. (2015), while studying the factors influencing the intention of the public to continuously use the online government office hall, fused the UTAUT model with trust theory to construct a research model of the intention of the public to continuously use the online office hall in Guangdong Province. They found through empirical analysis that effort expectations significantly and positively influenced the intention of the public to continuously use the online office hall. Finally, Gao (2012) explored the factors influencing the intention of college teachers to use online teaching methods consistently based on the UTAUT model. The study showed that effort expectations significantly and positively influenced the continued use intention of college teachers toward online teaching methods.

Based on this, we propose the following hypotheses:

H1: Performance expectations will significantly and positively impact the continuous use intention toward new technologies in agriculture.

H2: Effort expectations will significantly and positively impact the continuous use intention toward new technologies in agriculture.

2.3. Cooperative social impact and continuous use intention

Social impact (SI), which belongs to the category of psychology, refers to the social interactions of an individual in which he or she is influenced by others or groups, leading to a change in the attitudes, beliefs, and behaviors of the individual (Kelman, 1974). The "differential order pattern" characteristic of Chinese farmer cooperatives (Ye and Wei, 2016) has contributed to the formation of strong relationships with higher trust and tightness, providing influence or favors to people within the network (Granovetter, 1973), further helping cooperative members to accept information and new things (Luo et al., 2011). For example, Zhang et al. (2021) showed that farmers can obtain favorable information through their personal relationship networks as a way to compensate for the narrow government information channels and the weak information interpretation abilities of farmers. Then, for the average member of a farmer cooperative in a strong relational network, the strength of the relationship with other members determines its network position, which further affects access to resources and individual benefits. Therefore, the cooperative social impact of the continuous use of new agricultural technology for the members of the cooperative is the extent to which the continuous use of the technology is influenced by the president of the cooperative, the members of the board of directors, and other members of the cooperative.

Based on the research situation of Chinese farmer cooperatives, Chen and Liu (2018) stated that the sense of organizational belonging is an important factor affecting the enthusiasm and initiative of cooperative members. In addition, since farmer cooperatives have the dual attributes of enterprise and community, the innovation ability of the directors becomes an important factor affecting the development and performance of cooperatives (Hu, 2013). Therefore, this study shows that the social impact of cooperatives can be considered from the following two dimensions: an organizational sense of belonging and the innovation ability of the director.

There are numerous related studies. Tortoriello et al. (2012) found that information generated through regular interactions and exchanges can facilitate information sharing and resource exchange, thus helping to cope with the impacts of environmental changes and various uncertainties. Based on the perspective of relational networks among farmers, Yu et al. (2019) found that strong relationships can deepen trust among farmers, promote the formation of mutual cooperation and information-sharing mechanisms, and facilitate the adoption of new technologies. Finally, in their study of the participation of farmer cooperatives in agricultural technology extension, Zheng et al. (2017) found that strong relationships in cooperatives significantly and positively influenced the agricultural technology extension performance within cooperatives.

In summary, it is clear from the existing studies that strong relationships play a positive role in improving firm performance. Therefore, this study incorporates the unique attributes of farmer cooperatives and infers that cooperative social impact has a positive and significant effect on the intention of cooperative members to consistently use new agricultural technologies, with the following hypothesis:

H3: The cooperative social impact will significantly and positively influence the continuous use intention toward new technologies in agriculture.

2.4. Policy support and continuous use intention

According to the definition of the Organization for Economic Co-operation and Development (OECD), agricultural support policy is the support, subsidies, assistance, and aid given to farmers or agriculture in general by the government to increase the income of farmers or reduce their costs. For Chinese farmer cooperatives, their dual economic and social attributes dictate that they can play an active role in areas where the market allocation of resources is uneven or ineffective. However, farmer cooperatives are at a disadvantage in competition with other profit-making enterprises and need corresponding support from the government to improve the quality of agricultural products, increase the income of farmers, and promote the benign development of cooperatives. For example, Xu (2014) analyzed the characteristics of farmer cooperatives as a policy tool for the government to achieve "state intentions" from the perspective of empowerment theory and found that they determine the inevitability of government policy support. At the same time, policy support is also the "first driving force" for the development of cooperatives. Therefore, in this study, policy support refers to the relevant policies and technical training organized by the government to support and guide the members of farmer cooperatives in using new agricultural technologies in the agricultural production process.

Based on the research situation of Chinese farmer cooperatives, Luo et al. (2022) stated that technical training can play an important role in promoting the application of new agricultural technologies. In addition, since the Chinese farmer cooperatives follow the development path of "government support and farmer initiative," the continuity of government support policies is one of the considerations for promoting the application of new agricultural technologies (Liu, 2016). Therefore, this study suggests that policy support can be considered from the following two dimensions: technical training and policy stability.

There are numerous relevant studies on policy support. For example, Tate (2010) found through a survey of farmers in Shropshire, UK, that changes in European agricultural and environmental policies between 1997 and 2009 influenced the entrepreneurial behavior of farmers. Zhu and Kang (2013) found that policy support can positively influence the entrepreneurial intentions of farmers when they explored the logical relationship between the financial environment, policy support, and entrepreneurial intentions of farmers. Finally, in their study of the factors influencing the performance of cooperatives, Deng et al. (2021) found through empirical analysis that external support policies significantly and positively affected the performance of cooperatives.

In summary, policy support could have a positive effect on the intention to sustain the use of new agricultural technologies. In other words, a series of supporting policies formulated by the government, as well as technical training organized under the leadership of the government, would dispel the concerns of cooperative members about the continuous use of new agricultural technologies, enhance confidence in their continuous use, and have a positive impact on the continuous use intention toward new agricultural technologies. Therefore, this study infers that policy support has a positive and significant effect on the intention to sustain the use of new agricultural technologies and proposes the following hypothesis:

H4: Policy support will significantly and positively influence the continuous use intention toward new technologies in agriculture.

2.5. Moderating effects

In the UTAUT model proposed by Venkatesh et al. (2003), four moderating variables, namely, gender, age, experience, and voluntariness of use, indicate that individual characteristics and social factors are key factors to be considered for individual heterogeneity. Therefore, based on the UTAUT model, this study introduced the organizational model of farmer cooperatives as a moderating variable by combining the organizational characteristics of farmer cooperatives to explore the moderating effect on the intention to use new technologies consistently. This study argues that the organizational model of farmer cooperatives mainly refers to the different industrialized organizational and business models formed by vertical collaboration and vertical integration, among others, between farmer cooperatives and other agricultural business entities. In studying the mechanism of influence between government support and farmer cooperative regularization, Lin and Wu (2018) found that there is a moderating effect of the farmer cooperative organizational model in the relationship between government support and cooperative regularization. Moreover, Lu et al. (2017) showed that the demand for emerging agricultural technologies, as well as the rate of updating, varies among different models of farmer cooperatives.

Based on this, this study attempted to test whether the moderating effects of different organizational models of farmer cooperatives exist between performance expectations, effort expectations, cooperative social impact, and the intention to use new agricultural technologies consistently.

H5: The organizational model of farmer cooperatives will moderate the relationship between the performance expectations of members and continuous use intention toward new technologies in agriculture.

H6: The organizational model of farmer cooperatives will moderate the relationship between the effort expectations of members and continuous use intention toward new technologies in agriculture.

H7: The organizational model of farmer cooperatives will moderate the relationship between the social impacts of members and continuous use intention toward new technologies in agriculture.

In summary, this study proposes a research structure as shown in Figure 1.

3. Research design

3.1. Research subjects and data collection

In this study, data were collected using a web-based electronic questionnaire, and then, the research model of this study was tested empirically. This study was conducted to examine the intention of farmer cooperative members to continue using new technologies in agriculture, and therefore, the study population was set to include members of various types of farmer cooperatives within mainland

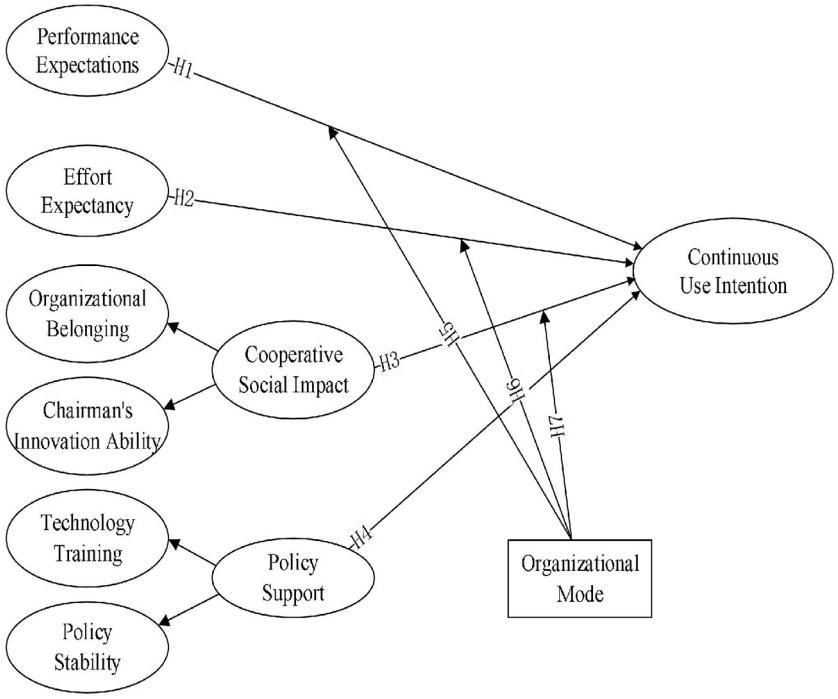

FIGURE 1
Theoretical framework.

China. To ensure that the questionnaire is logical, standardized, and organized, the standard "translation-back translation" method was used (Xia and Andrews, 2015). Seven scholars with experience in related fields were invited to complete the content revision to fit the research context of farmer cooperatives. An anonymous questionnaire was used to solicit respondents for this study to avoid issues of invasion of personal privacy. The questionnaires were distributed from 1 April 2021 to 31 May 2021, and a total of 509 questionnaires were collected. After removing invalid questionnaires, a total of 401 valid questionnaires were collected. The ratio of the sample size to sample question items in this study is 11.79, which satisfies the sample size requirement for empirical studies (Bagozzi and Yi, 2012).

3.2. Latent variable measurement

The questionnaire items were scored on a seven-point Likert scale ranging from strongly disagree (1), disagree (2), somewhat disagree (3), average (4), somewhat agree (5), agree (6), and strongly agree (7), with higher scores representing higher levels of agreement with the research variables. After the questionnaire items were designed, experts and scholars were invited to review the items and give their opinions. The design of each structure questionnaire is described as follows.

3.2.1. Performance expectations

In this study, the construct of performance expectations refers to the study by Zheng et al. (2020). The study defined performance expectations as the extent to which business users perceive that the adoption of new information technology will enhance business performance. This study adopts two items from its questionnaires. The original questions for the "performance expectations" section, such as "Using IIP will improve our productivity" and "Using IIP will improve our product quality," were revised by referring to the continuous use of new agricultural technologies. This study also adopted research by Tian and Yan (2020) on performance expectations by choosing the following two questions: "I think adopting e-commerce can reduce transaction costs" and "I think adopting e-commerce can increase revenue." Finally, the question "Blockchain technology increases my productivity" was modified with reference to Lobel and Phuong (2021) for exploring the performance expectations after the adoption of blockchain technology. There were a total of five items in the construct of performance expectations.

3.2.2. Effort expectations

The study by Ding and Xu (2019) was referred to for the construct of effort expectations of new professional farmers using the S&T information service system. This study revised the items "I think the scientific and technological information obtained through S&T information service is easy to understand and master" and "I think I can easily apply the information and knowledge provided by S&T information service in my work." In addition, the study of Bao (2017) was referred to by adopting "I think mobile learning devices are easy to use" and "I think I can easily apply information and knowledge provided by technology information services in my work." Finally, the study of Wissal et al. (2021) was referred to as "Interaction with IoT products for healthcare is easy for me." There was a total of 5 questions in this construct.

In this study, the variables of cooperative social impact were mainly measured by the sense of organizational belonging and the innovation ability of the director.

3.2.3. Organizational belonging

This study referred to the following three items of the Social Capital Measurement Scale of Gui and Huang (2008): "I feel at home in my neighborhood," "I like my neighborhood," and "I am proud to tell others where I live." This study also referred to the questions in Mark et al. (2019) "I felt accepted by my co-workers" and "I received good support from my co-workers," regarding the work relationship scale in companies. There was a total of five questions in this construct.

3.2.4. Innovation ability of the chairman

This study referred to the innovation ability of the measurement scale of chairman of the study by Zeng and Li (2016), including "you often have new ideas about cooperative system construction and product management," "you adopt new technologies and methods before your competitors," "you make bold decisions in the face of uncertainty," and "you prefer high-risk and high-reward projects." Furthermore, the question of Guo et al. (2019), "You are able to judge various changes in the market and develop a response plan," was adopted. There was a total of five questions in this construct.

The variables of policy support in this study were mainly measured by technical training and policy stability.

3.2.5. Technical training

In this study, we refer to the technical training measurement scale of the study by Ge et al. (2022), in which the following two questions were asked: "Cooperative members have many training opportunities" and "Training content is specific, practical and rich." In addition, according to the study by Zhu and Liu (2013), "The training on the use of Sakai was comprehensive," "The training improved the understanding of Sakai," "The training improved the proficiency of operation," and "The trainers were experienced and proficient in responding to questions" were revised to a total of five questions.

3.2.6. Policy stability

In this study, the items "the government has always paid high attention to technology entrepreneurship policies," "the technology entrepreneurship policies introduced in different time periods have a strong consistency," and "the government constantly adjusts the technology entrepreneurship policies according to the changes in the situation" were modified by referring to the item in the scale of policy continuity measurement by Peng et al. (2017), and a total of four questions were developed.

3.2.7. Continuous use intention

This study referred to the measurement scale "I would recommend other companies to use IoT technology" in the study by Dong and Hu (2020) on the willingness of logistics companies to use IoT technology consistently. Moreover, items of the study by Maroua (2018), "I intend to continue using the Blackboard for knowledge gathering," "I intend to continue using the Blackboard for knowledge construction," "I intend to continue using the Blackboard for knowledge sharing," and "Overall, I intend to continue using the Blackboard" were modified as questionnaire items. There was a total of 5 questions in this construct.

3.3. Data analysis

In this study, the results of the sample data were analyzed through three stages, namely, descriptive statistical analysis, measurement model validation, and structural equation modeling analysis. First, the descriptive statistical analysis of SPSS mainly completed the consistency analysis of facet measurement items. Second, based on the findings of Anderson and Gerbing (1988), this study completed the validation of the measurement model through reliability and discriminant validity. Confirmatory factor analysis (CFA) was used to confirm the reliability of the items and the internal consistency of the measurement using the composite reliability (CR) and average variance extracted (AVE). In addition, discriminant validity was tested by comparing the square root of the AVE value and correlation coefficients. Finally, based on the research model, path analysis and moderating effect analysis were performed on the structural equation model.

4. Results

4.1. Descriptive statistics

From the statistics of each question item (Table 1), the means of the seven latent variables in this study lie between 4.974 and 5.127, all of which are greater than the median, indicating that all seven latent variables are in the middle to upper range. The standard deviation was between 1.474 and 1.694, indicating a good consistency in the respondents'evaluation of the 34 measure items.

4.2. Measurement model verification

4.2.1. Reliability analysis

Fornell and Larker (1981) suggested that a critical value of 0.7 for the combined reliability value indicates the internal consistency of the measured question items for each construct. Therefore, in this study, confirmatory factor analysis of latent variables was performed to obtain standardized factor loadings (SFL), Cronbach's alpha, rho A, composite reliability (CR), and average variance extracted (AVE), and the results are shown in Table 2 for reliability analysis and the next step of validity analysis.

4.2.2. Discriminant validity

This study used the more rigorous average variance extracted (AVE) method to examine discriminant validity. Straub et al. (2004) suggested that the square root of the average variance extracted value (AVE) for each construct needs to be greater than the value of the correlation coefficient between the paired constructs. This indicates the discriminant validity among the constructs, as shown

TABLE 1 Question item analysis.

Construct	Item	Mean	Standard deviation
Performance expectations (PE)	PE1	5.000	1.621
	PE2	4.959	1.651
	PE3	5.005	1.651
	PE4	5.008	1.613
	PE5	4.951	1.630
Effort expectations (EE)	EE1	5.022	1.576
	EE2	5.016	1.609
	EE3	5.033	1.573
	EE4	5.049	1.572
	EE5	4.992	1.642
Organizational belonging (OB)	OB1	5.000	1.585
	OB2	4.978	1.592
	OB3	5.027	1.578
	OB4	5.003	1.600
	OB5	5.024	1.568
Chairman's innovation ability (CIA)	CIA1	4.973	1.586
	CIA2	5.005	1.534
	CIA3	5.043	1.581
	CIA4	5.092	1.539
	CIA5	5.008	1.572
Technology training (TT)	TT1	4.954	1.633
	TT2	4.997	1.694
	TT3	5.054	1.669
	TT4	4.965	1.689
	TT5	4.967	1.673
Policy stability (PS)	PS1	5.076	1.555
	PS2	5.011	1.515
	PS3	5.111	1.501
	PS4	5.106	1.474
Continuous use intention (CUI)	CUI1	5.084	1.449
	CUI2	5.152	1.557
	CUI3	5.117	1.527
	CUI4	5.090	1.527
	CUI5	5.090	1.545

in Table 3. The square root value of AVE corresponding to each variable was greater than the correlation coefficient with other variables, indicating that the measurement scale as a whole has good discriminant validity.

4.3. Structural equation modeling

4.3.1. Model goodness-of-fit test

In the structural equation modeling validation process, there is the problem that the model can explain the changes in the endogenous latent variables, but cannot fit the data well. Therefore, the goodness-of-fit (GOF) test was used in this study to determine the fitness of the model. According to Wetzels et al. (2009), the model fit is weak when the GOF is <0.25, moderate when it is between 0.25 and 0.36, and good when it is >0.36. In the present study, the criteria of the fit requirements were met, indicating that the model fit was good and the analysis of the structural model could be performed.

4.3.2. Path analysis

Table 4 shows the path coefficients, including performance expectations (t-value = 4.182 > 1.96, p-value <0.001), effort expectations (t-value = 3.897 > 1.96, p-value <0.001), policy support (t-value = 6.272 > 1.96, p-value <0.001), and cooperative social impact (t-value = 5.309 > 1.96, p-value <0.001), which all significantly affect continuous use intention. The findings support the research hypotheses of this model, with performance expectations, effort expectations, cooperative social impact, and policy support having 66.0% of the explanatory power to explain continuous use intention.

4.3.3. Moderating effects

In this study, the moderating effect analysis was completed using the Smart PLS 3.0 software. The results of the analysis in Table 5 show that, on the path of performance expectations on the continuous use intention, hypothesis H5 does not hold. On the path of effort expectations on the continuous use intention, hypothesis H6 is partially valid. On the path of cooperative social impact on the continuous use intention, hypothesis H7 is partially valid.

5. Conclusion and discussion

5.1. Academic contributions

This study attempts to explore the factors influencing the continuous use intention toward new agricultural technologies from the perspective of the members of farmer cooperatives in China based on the UTAUT model and the social impact and policy support dimensions of cooperatives. The results are obtained as follows.

5.1.1. Effect of performance expectations and effort expectations on continuous use intention

The results of the study showed that performance expectations have a significant positive effect on the continuous use intention toward agricultural technologies ($\beta = 0.167$, $p < 0.001$). In other words, the utility of the new agricultural technology itself, as well as the psychological expectations of the members of farmer cooperatives about the performance it brings, such as in terms of agricultural production efficiency and profitability, can influence the continuous use intention of cooperative members. The research results are consistent with the findings of Chen et al. (2017) and Ding and Xu (2019).

TABLE 2 Results of the confirmatory factor analysis.

Latent variable	Item	SFL	Cronbach's alpha	Rho A	CR	AVE
Performance expectations (PE)	PE1	0.913	0.956	0.956	0.966	0.851
	PE2	0.924				
	PE3	0.927				
	PE4	0.922				
	PE5	0.926				
Effort expectations (EE)	EE1	0.904	0.950	0.951	0.962	0.834
	EE2	0.922				
	EE3	0.907				
	EE4	0.910				
	EE5	0.923				
Continuous use intention (CUI)	CUI1	0.883	0.940	0.941	0.955	0.808
	CUI2	0.911				
	CUI3	0.894				
	CUI4	0.891				
	CUI5	0.904				
Organizational belonging (OB)	OB1	0.913	0.954	0.954	0.965	0.846
	OB2	0.918				
	OB3	0.924				
	OB4	0.924				
	OB5	0.919				
Chairman's innovation ability (CIA)	CIA1	0.912	0.949	0.949	0.960	0.829
	CIA2	0.910				
	CIA3	0.924				
	CIA4	0.902				
	CIA5	0.905				
Technology training (TT)	TT1	0.928	0.959	0.959	0.967	0.860
	TT2	0.927				
	TT3	0.926				
	TT4	0.928				
	TT5	0.928				
Policy stability (PS)	PS1	0.919	0.934	0.935	0.953	0.834
	PS2	0.923				
	PS3	0.905				
	PS4	0.907				

The results of the study showed that effort expectations have a significant positive effect on the intention to use new agricultural technologies consistently ($\beta = 0.170$, $p < 0.001$). It shows that the application of new agricultural technologies in the agricultural production process has certain requirements for the use of various terminal devices and platform software. The simplicity of the operation, the friendliness of the system interface, and the ease of reading and understanding agricultural information will affect the intention of cooperative members to use new agricultural technologies continuously. However, as new agricultural technologies are promoted and technical training is intensified, cooperative members learn and master new agricultural technologies faster, which makes it less difficult to use new agricultural technologies. They are more likely to use the system again, so the continuous use intention

TABLE 3 Results of discriminant validity tests.

	Effort expectations	Technology training	Continuous use intention	Policy stability	Chairman's innovation ability	Organizational belonging	Performance expectations
Effort expectations	**0.913**						
Technology training	0.535	**0.927**					
Continuous use intention	0.635	0.639	**0.899**				
Policy stability	0.606	0.620	0.707	**0.913**			
Chairman's innovation ability	0.536	0.556	0.646	0.608	**0.911**		
Organizational belonging	0.554	0.523	0.624	0.604	0.535	**0.920**	
Performance expectations	0.515	0.544	0.638	0.610	0.559	0.544	**0.923**

The bold diagonal line represents the square root value of AVE for each construct, while the lower triangle shows the Pearson correlation coefficient value between constructs.

TABLE 4 Path analysis.

Hypothesis	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	*t*-value (|O/STDEV|)	*p*-value	R^2
Performance expectations → Continuous use intention	0.167	0.168	0.040	4.182	0.000***	0.660
Effort expectations → Continuous use intention	0.170	0.172	0.044	3.897	0.000***	
Cooperative social impact → Continuous use intention	0.276	0.271	0.052	5.309	0.000***	
Policy support → Continuous use intention	0.331	0.330	0.053	6.272	0.000***	

***$p < 0.001$.

is strengthened accordingly. The findings are consistent with the view expressed by Wang (2014).

5.1.2. Cooperative social intention on continuous use intention

The results of the study showed that cooperative social impact has a significant positive effect on the continuous use intention toward new agricultural technologies ($\beta = 0.276, p < 0.001$). In other words, ordinary members who are within the relational network within farmer cooperatives are influenced by the recommended attitudes of other members within the cooperative in the decision-making process for the continuous use of new agricultural technologies, which is consistent with the findings of Guo et al. (2019). At the same time, to promote the benign development of farmer cooperatives, innovative directors are prone to promote and use new agricultural technologies within the cooperative and influence the willingness of members to continue using them through the "competent person effect," a finding consistent with that of Ye and Chen (2019).

The application of relational embedding theory to the study of the continuous use intention of farmer cooperative members toward the new agricultural technologies can explain the mechanism of the influence of network relationships within the cooperative on their willingness to use consistently. Ordinary farmers who join farmer cooperatives have their agricultural production and operation activities deeply embedded in the strong relationship network of farmer cooperatives. Therefore, in the decision-making process of the continuous use of new agricultural technologies, ordinary members not only judge through their own perceptions of the use of new agricultural technologies but also focus more on obtaining implicit knowledge of the utility of the use of new agricultural technologies through the strong relationship network to help them make the right choice to reduce uncertainty.

In particular, the innovation demonstrated by board chairs, who are at the nodes of strong relational networks of farmer cooperatives, led to the development of cooperatives. Through demonstration and leadership in the application of new agricultural technologies and information sharing, the chairpersons of farmer cooperatives are conducive to enhancing the confidence of ordinary members of cooperatives in the continued use of new agricultural technologies.

5.1.3. Impact of policy support on continuous use intention

The results of the study showed that policy support has a significant positive effect on the continuous use intention toward new agricultural technologies ($\beta = 0.331, p < 0.001$). In other words, when new agricultural technologies are used in agricultural production and operation, members of farmer cooperatives perceive the intensity of support from the supporting policies of the government and the effectiveness of the various types of training organized, which dispels their cost concerns about the continuous use of new agricultural technologies and thus promotes the benefits of cooperative members. The results are consistent with the findings of Deng et al. (2021).

The application of political embedding theory to the study of the willingness of farmer cooperative members to use new agricultural technologies consistently can explain the mechanism of

TABLE 5 Analysis of the moderating effect of the organizational model of farmer cooperatives.

	PE → CUI	EE → CUI	CSI → CUI
Path coefficients-diff (village elite leadership type vs. others)	0.312	0.613	0.938
Path coefficients-diff (village elite leadership type vs. government department driven)	0.016	−0.610	0.359
Path coefficients-diff(government department driven vs. leading enterprises driven type)	−0.176	0.040	0.018
Path coefficients-diff (others vs. government department driven)	−0.296	−1.223	−0.579
Path coefficients-diff (others vs. leading enterprises driven type)	−0.488	−0.573	−0.919
Path coefficients-diff (government department driven vs. leading enterprises driven type)	−0.192	0.650	−0.341
t-value (|village elite leadership type vs. others|)	1.007	1.228	1.887
t-value (|village elite leadership type vs. government department driven|)	0.149	5.121*	2.329*
t-value (|village elite leadership type vs. leading enterprises driven type|)	1.026	0.483	0.117
t-value (|others vs. government department driven |)	0.648	1.611	0.896
t-value (|others vs. leading enterprises driven type |)	0.863	1.054	1.619
t-value (|government department driven vs. leading enterprises driven type |)	0.753	5.096*	1.819
p-value (village elite leadership type vs. others)	0.315	0.221	0.061
p-value (village elite leadership type vs. government department driven)	0.881	0.000	0.021
p-value (village elite leadership type vs. leading enterprises driven type)	0.306	0.629	0.907
p-value (others vs. government department driven)	0.519	0.111	0.373
p-value (others vs. leading enterprises driven type)	0.390	0.294	0.108
p-value (government department driven vs. leading enterprises driven type)	0.453	0.000	0.070

PE, performance expectations; EE, effort expectations; CSI, cooperative social impact; CUI, continuous use intention.
*$p < 0.05$.

the effect of policy support on their continuous use intention toward new agricultural technologies. Based on the perspective of political embeddedness, the economic behavior of farmer cooperatives, as special economic subjects, is influenced by the political environment, power structure, and industrial policies in the process of interaction with government departments. Therefore, farmer cooperatives, which are formed by the union of scattered small farmers, can obtain government policy support through political embedding. It helps cooperatives obtain various resources, including agricultural projects and policy preferences, to promote the benign development of cooperatives. Since the organizational model of farmer cooperatives, in addition to being led by village elites, also includes models such as leading enterprises and government departments, while gaining legitimate social recognition, farmer cooperatives led by leading enterprises and government departments need to actively integrate into the village society to overcome "externalities" and play a role in promoting the use of new agricultural technologies throughout the village by leveraging the weak "government-public" duality among ordinary farmers (Zhao, 2019).

The empirical study found that the four main variables, namely, performance expectation, effort expectation, cooperative social influence, and policy support, have the following strengths on the intention to continue using them: policy support (0.331) > cooperative social influence (0.276) > effort expectation (0.170) > performance expectation (0.167). The results indicate that the highest intensity of influence was found for policy support, reflecting the dominant role of policy support on the willingness of cooperative members to use new agricultural technologies consistently. This is consistent with the view expressed by Xu (2014) that "policy support is the 'first driving force' of cooperative development." The strength of the impact of cooperative social influence ranked second, reflecting that cooperative social influence plays a facilitating role in the willingness of cooperative members to use the AI system consistently, which is consistent with the findings by Tan et al. (2017).

5.1.4. Moderating effects

In this study, hypothesis H5 was not supported, and both H6 and H7 were partially supported. The empirical study found that the organizational model of farmer cooperatives did not have a moderating effect on the path of performance expectations on continuous use intention. Hypothesis H5 does not hold. A possible explanation is that members of farmer cooperatives in the same organizational model have homogeneity of property rights structure, surplus distribution, and other systems so that the expectation of returns of cooperative members does not influence their continuous use intention toward new agricultural technologies.

The organizational model of farmer cooperatives possesses a partial moderating effect on the path of effort expectations on continuous use intention, i.e., hypothesis H6 partially holds. A possible explanation is that farmer cooperatives with different organizational models have different levels of demand for new agricultural technologies and different rates of updating (Lin and Wu, 2018), and the intensity of the introduction of new agricultural technologies is as follows: "Leading enterprises driven type" > "Government department driven" > "Village elite leadership type" > "other" types. Then, for cooperative members, the cost of time and effort to master new agricultural technologies varies among farmer cooperatives in different organizational models due to the various introduction and update rates of new agricultural technologies having a significant impact on their continuous use intention.

The organizational model of farmer cooperatives possesses a partial moderating effect on the path of the cooperative social impact on continuous use intention, i.e., hypothesis H7 partially holds. A possible explanation is that the homogeneous differences possessed by the internal network relations of farmer cooperatives

with different organizational models affect the dissemination of tacit knowledge (Granovetter, 1973; Lu et al., 2017). Then, it is easier for cooperative members to acquire tacit knowledge about new agricultural technologies to help them cope with economic risks and uncertainty shocks when making decisions about the continuous use of new agricultural technologies, such as the "Village elite leadership type." The inclusion of enterprise representatives or government agents in the "Leading enterprises driven" and "Government department driven" organizational structures not only enhances the accessibility of resources for cooperative members but also reduces the dissemination of tacit knowledge and leads to a reduction in the homogeneity of internal network relationships, which is characterized by "weak relationships" and affects the intention toward cooperative members to continue using them.

5.2. Management insights

Based on the results of this study, the following recommendations are made to promote relevant policies to enhance the continuous use intention of cooperative members toward the new agricultural technologies.

First, the agricultural sector of government can strengthen policy guidance. The policy support component of the study shows that policy support is the most critical influencing factor for the intention of farmer cooperative members toward the continuous use of new agricultural technologies. Therefore, it is recommended that government departments effectively promote the implementation of new agricultural technologies in the field of agricultural production by enhancing the support of relevant policies, increasing investment in education and training, and ensuring the continuity and stability of supporting policies.

Second, farmer cooperatives focus on the training and introduction of talents. This study found that the rational allocation of talent laddering in agricultural cooperatives has an important role in promoting the benign development of cooperatives. Therefore, it is highly recommended that farmer cooperatives should combine their realities and strengthen the capacity cultivation of their directors through short-term study tours, training visits, forums, and exchanges. Moreover, they should focus on cooperative members and young farmers and on the internal excavation and cultivation of reserve talents through the cooperative system and relevant professional learning. Finally, they should broaden the channels to introduce talents, adhere to the policy of introducing as needed and flexibly, and hire professional managers with rich management experience, profound technical knowledge, and strong competitive consciousness through contractual constraints, equity incentives, and a combination of full-time and part-time jobs to realize the benign development of professional cooperatives of farmers.

Third, farmer cooperatives strengthen internal governance. The study of the social impact component of cooperatives shows that the sense of organizational belonging of cooperative members plays a helpful role in strengthening intra-cooperative network relationships and the dissemination of tacit knowledge about new agricultural technologies. Therefore, it is suggested that farmer cooperatives cultivate the sense of ownership of cooperative members, strengthen the strength of internal networks, enhance their sense of organizational belonging, and promote the use of new agricultural technologies by optimizing the existing internal management system, establishing an information communication mechanism and building a cooperative culture. Therefore, it is suggested that farmer cooperatives cultivate the sense of ownership of cooperative members, strengthen the internal networks, enhance their sense of organizational belonging, and promote the use of new agricultural technologies by optimizing the existing internal management system, establishing an information communication mechanism, and building a cooperative culture.

5.3. Research limitations and future developments

This study mainly focused on Chinese farmer cooperative members and collected sample data through a questionnaire survey. The sample data are cross-sectional and do not reflect the dynamics of the variables. The causal explanatory power of the mechanisms that lead to the influence of the continuous use intention toward the new agricultural technologies is insufficient, and future studies may further consider the use of longitudinal studies for validation. In addition, this study constructs a theoretical model from the perspective of farmer cooperative members to study the factors influencing continuous use intention. It does not consider factors such as satisfaction and performance, and future studies, as needed, can include other factors into the model to be studied.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

FJ's contribution includes ideas, formulation of overarching research goals and aims, and writing. RZ's contribution includes data collection and writing original draft preparation. JL's contribution includes software operation and reviewing. All authors contributed to the article and approved the submitted version.

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.

Publisher's note

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Nature conservation versus climate protection: a basic conflict of goals regarding the acceptance of climate protection measures?

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Transformation processes are embedded in a broader discourse on sustainability, climate protection, and biodiversity protection. In this context, possible interindividual conflicts between an interest in nature conservation and efforts to counteract climate change also seem to be relevant. This study focuses on the acceptability of different climate protection measures with possible impacts on landscapes, habitats, and human recreation. Based on a survey of a representative sample (N=1,427 participants), the impact of conservation-related beliefs on the acceptance of four different climate protection measures was analyzed with respect to possible conflicts with values and norms relevant to climate protection. The study focuses in particular on potential value-based conflicts, as this type of conflict is classified as non-negotiable in negotiation processes and thus represents a particular social challenge. Also, to consider the possible relevance of political orientation and humanity orientation, eight structural equation models were tested. Results showed similar structures for the acceptance of the four climate protection measures. There did not seem to be value-based conflicts between nature conservation and climate protection, as the results showed substantial similarities between nature conservation beliefs grounded in biospheric value orientation (protecting biodiversity) and values and norms relevant for climate protection. Political orientation seemed to be relevant as well, as left-oriented people were more likely to accept the four climate protection measures that were tested. However, the relationship between political orientation and acceptance of the measures was – without exception – mediated by the personal norm.

KEYWORDS

nature conservation, climate protection, conflict of goals, biospheric value orientation, personal norm, political orientation, global human identity

1. Introduction

Climate change and the associated urgent need for climate protection measures have become central challenges that our society faces. The Intergovernmental Panel on Climate Change (IPCC) has made it clear that the goal of the Paris Agreement to limit global warming to 1.5 degrees is still possible but requires immediate action and appropriate climate policy measures

(IPCC, 2022). In this context, the shift toward a sustainable and climate-friendly economic system (D'Amato et al., 2017; Jaeger-Erben et al., 2021; Thrän and Moesenfechtel, 2022) requires the use of renewable energy and renewable resources for material use.

The development and implementation of renewable energy technologies (e.g., wind turbines, photovoltaic systems, and wood energy plants), the transformations of energy systems (e.g., electrification, decarbonization, defossilization, biologization, and decentralization), and associated climate and energy policies (e.g., Paris Agreement; United Nations Framework Convention on Climate Change; Renewable Energy Directive, European Union; Renewable Energy Act, Germany) have already been intensively researched and discussed – especially for the power sector (Jacobsson and Lauber, 2006; Rogelj et al., 2015; Bush, 2020; Haji Esmaeili et al., 2020; Malladi and Sowlati, 2020; Nian et al., 2022).

The expansion of renewables and the promotion and use of other sensible technologies to mitigate global warming can succeed only if the citizens support the associated political measures that support such technologies and their implementation. In particular, the acceptance of the construction and repowering of wind power plants has already been intensively investigated in this area (e.g., Devine-Wright, 2005; Wüstenhagen et al., 2007; Ek and Matti, 2015; Petrova, 2016).

In this context, it is first necessary to precisely define the concept of acceptance. Wüstenhagen et al. (2007) distinguished three levels of acceptance, namely, *community acceptance, socio-political acceptance,* and *market acceptance*. While community acceptance refers to the project level, and focuses on a specific, local plant project, socio-political acceptance refers to the social acceptance of the technology on a more general level, and market acceptance describes the process by which the market adopts the technological innovation (Wüstenhagen et al., 2007).

This paper focuses on the socio-political acceptance of selected climate policy measures and examines relevant predictors. Although acceptance of or concerns about local projects or specific plants are not considered in the following, we assume that the possible predictors analyzed in this study (values, beliefs, norms, political orientation, and global human identity; see below) might also be relevant for understanding community acceptance. Nevertheless, the local context will play a major role and must be considered in these cases as well, and research focusing on community acceptance, has to take into account the specific situational factors as well as the perception of procedural justice (Tyler, 2000) and/or distributional justice (Adams, 1965).

While the socio-political acceptance of the extension of renewable energies with the aim of climate protection is relatively high in Germany, for example[1] (BfN (Bundesamt für Naturschutz), 2022), there are definitely local protests, especially with regard to the extension of onshore wind power plants (Fachagentur Windenergie (FA Wind), 2021). The reasons for these protests are mainly protests against intrusions that change the landscape, harm biodiversity by destroying sensitive habitats, but also the potential that local residents will be annoyed by the anticipated noise of wind power or by wind turbine obstruction lights [Fachagentur Windenergie (FA Wind), 2019; Quentin, 2019; Pohl et al., 2021; Gaßner et al., 2022; Kopernikus-Projekt Ariadne, 2022].

In addition to the choice of renewable energy technologies and certain locations (van der Horst, 2007), several other factors can have a critical influence on both the socio-political acceptance of technologies and measures and the overall success of the transition process: the actual design of the transformation process (participation, procedural and distributive justice; Heleno et al., 2022; Reitz et al., 2022), the characteristics and perceptions of a problem (Wolsink, 2007; Beer, 2021), and the choice of policy instruments (Böcher, 2012; Barnea et al., 2022; Berker and Böcher, 2022). Social opposition against renewable energy – concerning local plants or renewable energy technologies and climate protection measures in general – or other innovative technologies can be based on different motives, different values, and conflicting goals (Baasch, 2021; Baasch et al., 2021; Berntsen et al., 2021; Sovacool et al., 2022; Zawadzki et al., 2022).

Protests based on local residents' *annoyance* with renewable energy plants are (mainly) directly linked to the characteristics of these specific plants and can therefore be understood as particular conflicts of interest between specific groups from the population (residents) and the planned extension of renewable energies. Protests based on fears of endangering habitats and impairing biodiversity, on the other hand, could also refer to a fundamental conflict in goals between nature conservation goals and climate protection goals. For example, wind turbines might pose a threat to birds and bats, and the construction of solar panels could take up land that may be lost for conservation purposes. These goal conflicts could also be expected for other relevant climate protection technologies that are also associated with landscape interventions and impairment of habitats, such as technologies associated with forest management for carbon benefits such as wood for the building sector (Eisele and Juschka, 2022; proHolz Bayern, 2022). Does this expectation imply that there is a fundamental conflict of interest between nature conservation and climate protection and that nature conservationists and climate protectionists are opposing each other?

We do not want to suggest that the goals of nature conservation and climate protection are fundamentally contradictory. For example, a joint publication by the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Pörtner et al., 2021) argues for a close causal link between climate protection and nature conservation. Even though it appears plausible that the conservation of biodiversity and habitats depends on the mitigation of climate change, the conflict between climate protection and nature conservation goals seems to be a socio-political problem, at least in Germany. Possible conflicts of goals here might partly be due to the fact that from the nature conservation perspective, climate protection is promoted at the "expense of nature," i.e., nature is not primarily seen as a *victim* of climate change, but as a *resource* for solving the problem (BUND, 2009; Carstens, 2013; Schultz, 2020). In addition, there are indications of right-wing political interventions in nature conservation that instrumentalize nature conservation motives politically in order to intensify a conflict of goals between nature conservation and climate protection and thus also suggest an underlying conflict of values [for a critical overview see FARN (Fachstelle

1 According to a representative survey of N=2,044 people conducted in 2019 by the German Federal Agency for Nature Conservation, only 8% of respondents reject the extension of renewables in principle (BfN (Bundesamt für Naturschutz), 2022).

Radikalisierungsprävention und Engagement im Naturschutz), 2019; Gottschlich and Katz, 2020; NABU (Naturschutzbund Deutschland), 2022].

1.1. Types of conflicts between nature conservation motives and climate protection motives

We would like to start with a brief description of different causes of disputes or possible types of interindividual conflicts between nature conservation motives and climate protection motives. Moore (2014) proposed the subdivision of (1) conflicts of interest, (2) relationship-based conflicts, (3) value-based conflicts, and (4) structural conflicts. In real life situations, there are quite often mixed forms of types of conflicts, or several types of conflicts occurring at the same time. It is nevertheless important to make these distinctions because different types of conflicts have very different consequences for possible conflict management and negotiation.

In the following we will not deal more intensively with relationship-based conflicts and structural conflicts, because relationship-based conflicts can occur in all areas of social life, while the management of structural conflicts requires information about the respective situation-specific and local parameters. So let us take a closer look at possible conflicts of interest and possible value-based conflicts. Conflicts of interest are always embedded in a more or less complex, specific context, i.e., involved groups or individuals pursue different goals in a specific situation, or at least believe that goals are incompatible. As long as there are no underlying conflicting values, these goals are basically negotiable. An appropriate solution strategy for a real conflict of interest would be to convert positions into interests in order to negotiate compromises or compensations. Such a conflict of interest could exist, for example, if residents feel annoyed by the noise or obstruction lights from wind turbines.

The picture is different in the case of value-based conflicts, that pose a particular challenge for conflict mediation: Values are basically considered to be difficult, if not impossible, to negotiate (Illes et al., 2014; Stöckli and Tanner, 2014). In these cases, it is sometimes reasonable only to examine the extent to which it is at least possible to develop overarching common goals.

For example, if conservation-related reasons are cited against the expansion of specific renewable energy plants or forestry technologies, it is important to understand whether these are conflicts of interest that are *fundamentally negotiable* or whether there is an underlying conflict of values that may inhibit the identification of common overarching goals and thus hinder the resolution of the conflict.

This may illustrate the importance of analyzing whether societal disputes about climate and/or nature protection measures are based on value-based conflicts or whether these can rather be neglected and thus the opportunity for negotiation is given.

Before we try to shed light on this question empirically, we first take a closer look at relevant conservation-related values and beliefs and deduce the extent to which these might come into conflict with values and beliefs that are relevant to climate protection. We complement our perspective by considering political orientation and global human identity as other possible contributing factors in this context.

1.2. Relevance of values, beliefs, and norms for nature conservation or climate protection

In the following, we discuss possible relevant values/value orientations and beliefs as predictors of environmental protection/climate protection and nature conservation. We do not claim to present an entire list of relevant factors that (might) have an impact on pro-environmental behavior and/or conservation behavior, but deliberately focus on values and norms. As already mentioned, we consider it particularly important to look for *value-based conflicts* in the domain of socio-political acceptance of climate and nature protection measures. Approaches that rely mainly on rational choice models and thus can explain environmental behavior quite successfully, such as approaches in the tradition of the Theory of Planned Behavior (TPB, Ajzen, 1991), are therefore excluded from the following description.

The distinction of environmental protection/climate protection on the one hand side and nature conservation on the other hand side is of primary importance for this paper, so we have deliberately limited ourselves to refer to studies that explicitly separate nature and the environment or nature conservation and environmental/climate protection. We will start with the area of nature conservation and then move on to climate protection.

There is already a longer social-empirical research tradition dealing with approaches for explaining conservation motives. Among others, the egocentric-anthropocentric dimension has been used to explain the relevance of values (e.g., Stern and Dietz, 1994). However, the suggestion of an "egocentric-anthropocentric" dimension seems to be an oversimplification of the rather complex structure of beliefs and values regarding nature and conservation (Buijs et al., 2006; Buijs, 2009). Nature-related beliefs seem to be more associated with the (cognitive) image of nature, e.g., concepts about the relationship between nature and culture or the fragility of nature (Fischer and van der Wal, 2007; Buijs, 2009), whereas nature-related values reflect the normative dimension. Because we are interested primarily in possible conflicts between nature conservation and climate protection in this paper, we mainly refer to this normative dimension in the following.

According to Rockeach (1973), values can be understood in terms of standards that serve as guiding principles in a person's life, are stable over time, and are rather general and independent of concrete situations. Stern et al. (1995) offered a link between basic values (Schwartz, 1992) and environmental value orientations. They took items from Schwartz's value instrument to reflect egoistic (at the level of one's own person), social-altruistic (at the level of other people), and biospheric (at the level of non-human life) value orientations. More recent studies have also taken into account the significance of value orientations for the context of nature conservation (Martin and Czellar, 2017; Fornara et al., 2020; Molinario et al., 2020). Fornara et al. (2020) analyzed committed action for nature and biodiversity based on an extended version of the value-belief-norm theory in 7 European countries and were able to demonstrate a direct influence of biospheric values not only on norms but also directly on action toward biodiversity. Martin and Czellar (2017) focused on biospheric values as well: Based on samples from Europe and North America, they were able to show that connectedness to nature seems to have a positive impact on biospheric value orientation and that biospheric value orientation might mediate the influence of connectedness to nature on behavior. Ojea and Loureiro (2007) found evidence that egoistic as well as altruistic value orientations may increase

the financial support of a wildlife protection program. In general, nature conservation measures can be justified by all three value orientations. Thus, altruistic value orientations are linked to the desire to preserve recreational landscapes (landscape conservation) as well as the natural foundations of life for future generations (biodiversity conservation). Biospheric value orientations would lead people to support nature conservation policies independently of their usability for humankind (biodiversity conservation), and the personal desire for recreation might motivate people to support landscape conservation policies–in order to maximize the individual outcome (landscape conservation).

Values (or value orientations) and norms have also been analyzed regarding their significance for sustainable behavior and *climate protection behavior*. A number of studies have already shown that personal norms are important predictors of a variety of environmentally friendly behaviors (Hunecke et al., 2001; Nordlund and Garvill, 2003; Thøgersen, 2006; Bamberg et al., 2007). A personal norm (PN) refers to a person's conviction that a certain behavior is right or wrong. Thus, the central feature of PN is internalization, and PN is independent of the perceived expectations of others or possible social sanctions (Bamberg et al., 2007). A body of studies have provided empirical evidence that environmental value orientations also contribute to the explanation of pro-environmental behaviors (Nordlund and Garvill, 2003; Steg and de Groot, 2012; Steg et al., 2014). Marshall et al. (2019) investigated not only problem awareness but also the importance of value orientation for self-reported environmental behavior in a specific region–the Australian Great Barrier Reef, which is severely affected by climate change. Based on a sample of N = 1,934 inhabitants of this region, an influence on environmental behavior was demonstrated for altruistic and biospheric values. When talking about pro-environmental behavior (and the support of climate action), PN and environmental value orientations do not seem to be independent of each other. For example, studies by Thøgersen and Grunert-Beckmann (1996) as well as Nordlund and Garvill (2003) showed a mediating effect of PN on the influence of values. This is also consistent with the assumptions of the value belief norm model (VBN) proposed by Stern and Dietz (1994) and Stern (2000), and that is rooted in the assumptions of the norm-activation model (Schwartz, 1977; Schwartz and Howard, 1981) and the New Environmental Paradigm (NEP) of Dunlap and Van Liere (1978).

According to Stern's conception (Stern, 2000), the support of climate protection measures (here, the implementation of or transition to renewable energy technologies and the shift to renewable resources that serve as carbon sinks) can be understood as a facet of pro-environmental behavior. Given the relevance of biospheric values in influencing pro-environmental behavior (Steg and de Groot, 2012; Steg et al., 2014), we would expect biospheric value orientations to be significant motivators of support for policies for both nature conservation and climate protection. However, not only human values but political orientation, too, seem to have significant impacts on concerns about climate change.

1.3. The roles of political orientation and global human identity in the acceptance of climate protection measures

Parallel to studies addressing climate-protection-related values and conservation beliefs with respect to climate protection measures, there is also some evidence that political orientation is relevant to the awareness that the climate crisis is a serious problem and the way in which people evaluate climate protection measures. McCright et al. (2016) reviewed studies that analyzed the relationship between political orientation (left–right ideology) and climate change views in the United States and in European Union countries. Compared with the US, organized denial campaigns seem to be less prominent in the EU. Also for Western European countries, there seems to be stronger support for climate action for citizens on the left than for citizens on the right (except for former communist countries). Carrus et al. (2018) also took a closer look at the role that political orientation plays in relation to environmental attitudes and climate change denial. In line with McCright et al. (2016), they too found evidence that a left-wing or liberal political ideology is more likely to lead to pro-environmental behavior and argued for a more complex analysis of the (psychological) conditions for political ideology and the associated effects.

Boulianne and Belland (2022) analyzed the influence of left–right political orientation in a study with a climate-specific focus (e.g., belief in climate change, support for climate policies, trust in science) and were able to show that a right-wing orientation (mediated by trust in the media and science) had a negative impact on belief in climate change. These results are in line with a similar study by Gregersen et al. (2020).

While there was also the expected positive effect of education on belief in and support for climate policies, this effect seemed to be significantly stronger for a left-wing political orientation, whereas it was in some cases not even significant for a right-wing political orientation (Czarnek et al., 2021). Due to a lack of problem awareness and the associated lower salience of climate policies, a more right-wing political orientation appears to have a negative impact on energy-saving behavior (Gregersen et al., 2021) as well as on the acceptance of climate policy measures, such as additional taxation of fossil fuels (Fairbrother et al., 2019). In this context, counterfactual arguments, fake experts, and misinformation can influence public opinion and might be used strategically by interest groups to bolster their own political agenda (Bush, 2020; Bertolotti et al., 2022; Boecher et al., 2022; Schmid-Petri and Bürger, 2022).

Although we would expect political orientation to show an influence on the acceptance of different climate protection measures, it remains unclear which possible lines of conflict are covered by this right–left dichotomy. Since the 1990s, political orientation has been assumed to run along (a) the socioeconomic conflict between social justice (left) and liberal market freedom (right) and (b) the socio-cultural conflict between liberalism/cosmopolitanism (left) and authoritarianism/conservatism (right; Decker, 2019). With regard to the socio-cultural conflict, we see parallels here with the discussion of the idea of a global identity for the context of the perception and assessment of global climate change (Reese et al., 2015; McFarland et al., 2019; Loy et al., 2022).

Global identity can be understood as a specific type of social identity. The social identity perspective attempts to supplement the previous more individualistic research perspective, that focusses on the impact of internal variables like norms, values, and attitudes to explain people's pro-environmental behavior. The social identity perspective is focused on the relevance of a kind of self-categorization, that means that people define themselves as being part of a group (social identity) and as individuals (Ferguson et al., 2016; Fritsche

et al., 2018; Loy et al., 2022). In the context of research on climate change, a specific type of social identity, namely global identity, has become more relevant and reflects the identification with all humanity (for an overview see Loy et al., 2022). People who were more likely to consider themselves global citizens also seemed to take the impact of climate change more seriously (Running, 2013), and were more angry about climate injustice (Barth et al., 2015). Loy and Reese were also able to show that identification with people around the world was positively related to support for climate action (Loy and Reese, 2019). There are already promising findings concerning the importance of global identity for climate action and pro-environmental behavior, although the exact interplay of internal factors such as norms and values, and human identification remains unclear. The results of a meta-analysis by Agostini and Van Zomeren (2021) support the idea of parallel processes.

Above all, political orientation and self-transcending values (e.g., biospheric values) seem to be among the most consistent and meaningful predictors (Hornsey et al., 2016), although they do not seem to be effective in isolated ways. Using data from 16 Western European countries, Smith and Hempel (2022) analyzed the direct and interactive effects of political orientation and human values on attitudes and behaviors related to climate change. They were able to show that the moderating effects of political orientation were strongest for positive self-transcendence and negative conservation values.

1.4. Research questions and research aims

Having addressed the relevance of biospheric values, personal norm, and nature protection beliefs to the acceptance of conservation measures or climate protection measures as well as the roles of political orientation and global human identity, we now return to the central issue of this paper, namely the possible value-based conflicts between nature conservation and climate protection regarding the acceptance of concrete climate protection measures. The study presented here does not aim at testing a full-fledged model to explain the socio-political acceptance of climate mitigation measures. Instead, we are interested in illuminating the specific aspect of possible value-based conflicts between nature conservation motives and climate protection motives.

These potential conflicts might not manifest themselves in the same way for different climate protection measures. In this study, we considered a total of four different measures, some of which have different assumptions (see Figure 1).

We expected that a biospheric value orientation (BV) would have a positive impact on the acceptance of different climate protection measures. We expected this effect for all four of the measures we considered. In this context, we also expected a significant influence of the personal ecological norm (PN) on all measures. In accordance to the assumptions of the VBN we expect mediating effects of PN on the influence of values for all four of the measures. Regarding value orientations and conservation beliefs, the dependencies could be somewhat more complex. Values (defined as guiding principles in life) provide the basis of Nature Conservation Beliefs (NCB). These beliefs are not comparable to the New Environmental Paradigm Scale (NEP) in the context of the VBN. While the NEP reflects a pro-environmental worldview on a more general level, Nature Conservation Beliefs (NCB) are more specific. If nature conservation is primarily based on the preservation of biodiversity as a value in itself, independently of its usability for humankind (biospheric value orientation), this could–although not necessarily–lead to the rejection of measures for the expansion of renewable energies, insofar as these measures are associated with changes in the landscape (energy generation from wind turbines, energy generation from free-field photovoltaic systems) or the associated impairment of habitats (forest management measures for carbon benefits: building with wood instead of cement). In this context, it should be mentioned that in relation to building with wood, not everyone will see the connection between this measure and forest management measures and the interference with existing habitats. If nature conservation is justified by the recreational value of nature, this belief might also conflict with landscape alteration measures (generating energy with wind turbines, generating energy with free-field photovoltaic systems). Even if building with wood also has landscape-altering consequences due to the necessary forestry management measures, there is not necessarily a conflict here because this effect might not be represented at all.

As pointed out, there is some evidence that political orientation and humanity orientation can have an influence on the acceptance of climate protection measures. In a similar way that values form the basis for conservation beliefs and for norms, we also assume that political orientations and human identity function in the sense of a fundamental, context-independent guideline and influence conservation beliefs and norms. The present study is aimed at illuminating in more detail the possible interrelationships between political orientation, global human identity, and both nature-conservation-related and climate-protection-related beliefs and value orientations in order to identify and better understand possible underlying value-based conflicts.

2. Materials and methods

2.1. Participants and procedure

The data reported here are part of a larger survey involving an interdisciplinary group of researchers. The overall survey examined climate change mitigation strategies, climate change mitigation behaviors, and political support for climate change mitigation technologies. In the following, only the survey measures that have been implemented to analyze possible conflicts between nature conservation motives and climate protection motives in the scope of the acceptance of climate protection measures are presented in more detail. The data were collected in an online survey from April 22nd to May 19th, 2022, Germany-wide. The company Bilendi was commissioned to recruit a stratified sample.[2] $N = 4{,}600$ people visited the link and 1,584 finished the online questionnaire. The sample was stratified to be representative of the German population regarding age (for the 16 to 74 olds), gender, education, and place of residence, reflecting the distributions of those characteristics in the general German population. The criterion "place of residence" was based on the distribution statistics of the German population according to municipality size classes (Statistisches Bundesamt, 2023) to realize a

2 The participants received a financial compensation.

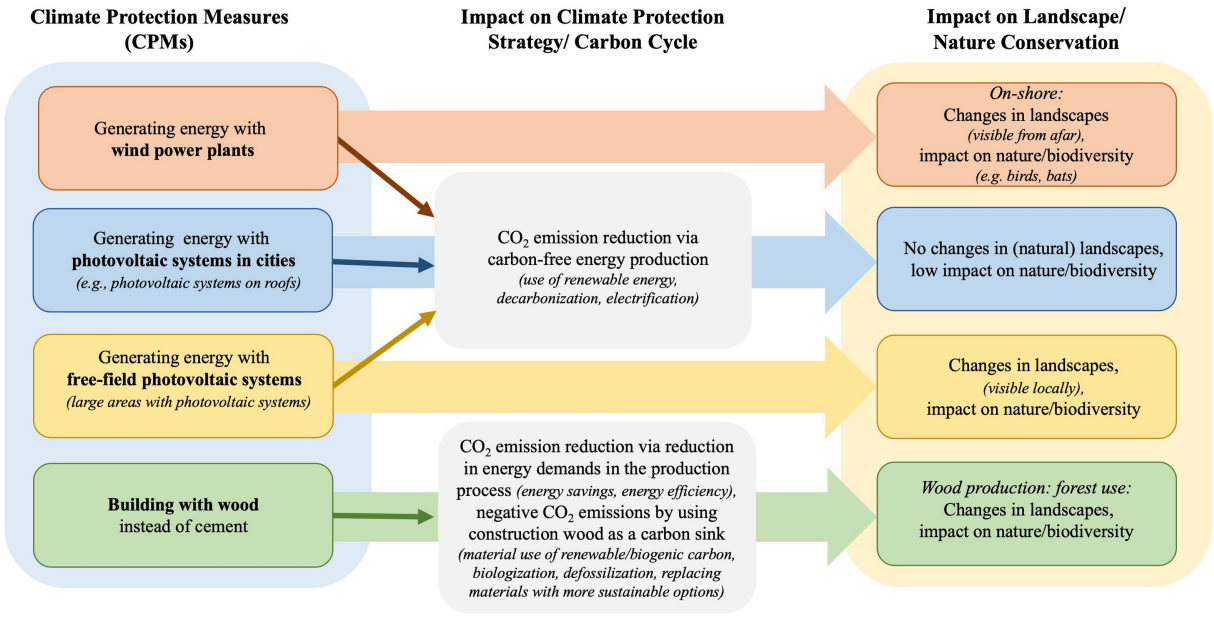

FIGURE 1
Climate protection measures and their impact on climate and nature.

representative distribution of the sample with regard to urban–rural areas. After unreliable cases were excluded on the basis of participants' answering time, missing values, and unrealistic answers to open questions, a total of $N = 1{,}427$ participants formed the final sample. Participants' age ranged from 16 to 74 ($M = 47.18$, $SD = 15.94$). 50.2% were female, 49.7% were male, and 0.1% identified as diverse. Regarding participants' highest level of education, 1.9% did not have a school degree (yet), 6.3% reported a secondary school diploma but had not completed an apprenticeship, 31.4% reported a secondary education, 24.7% reported a secondary school diploma and had completed an apprenticeship, 17% had a higher-education entrance qualification, and 18.6% had completed higher education.

Because some psychological variables showed high percentages of missing data, we conducted a missing value analysis. As Little's MCAR-Test (Little, 1988); $\chi^2\,(141161) = 143518.41$, $p < 0.001$ suggested that the missing data were on a continuum between missing at random and not missing at random and as the missingness of the data was moderately to highly correlated with other variables, the estimation maximization method with NORM Version 2.03 was chosen as an appropriate method for imputation (Schafer, 1999). The items measuring the acceptance of climate protection measures were excluded from the imputation because only participants who knew those measures answered the respective questions. Figure 2 provides an overview of the mediation hypotheses.

2.2. Measures

2.2.1. Personal norm for climate protection

We measured participants' personal norm (PN) for climate protection with three items taken from Matthies and Merten (2022) with reference to Schwartz and Howard (1981). The three items ("No matter what other people think, it is important to me to get involved in climate protection"; "Because of my values, it is important to me to support climate protection measures"; "I feel obligated to save CO2 in my everyday life") were answered on a 5-point Likert scale (1 = completely disagree; 5 = completely agree). We choose to measure a rather broad PN concept focusing on individual climate protective behavior to predict a range of differently characterized policy measures. The items had high reliability ($\omega = 0.93$) and large standardized factor loadings ($0.87 \leq \lambda \leq 0.93$; in a unidimensional CFA with robust Maximum Likelihood (MLR) estimation).

2.2.2. Biospheric value orientation

Participants' biospheric value orientation was measured with three items from the Brief Inventory of Values by Stern et al. (1998) ("Protecting the environment, preserving nature"; "Respecting the earth, harmony with other species"; "Unity with nature, fitting into nature"). Each item was rated as a "guiding principal in my life" on a 9-point Likert scale (−1 = opposed to my values; 0 = not important, 1 = unlabeled, 2 = unlabeled, 3 = important, 4 = unlabeled, 5 = unlabeled, 6 = very important, 7 = extremely important), that has already been used by Schwartz (1992).[3] These items showed a sufficiently high reliability ($\omega = 0.87$), and the unidimensional CFA[4] yielded appropriate standardized factor loadings ($0.78 \leq \lambda \leq 0.88$; MLR estimation).

3 Stern et al. (1998) decided for a simplified 7-point scale because their interviews were conducted *via* telephone.

4 For a CFA model that combined PN and BV, used MLR estimation, and allowed the two latent factors to correlate ($r = 0.64$), the fit indices indicated good to excellent model fit (robust CFI=0.992, robust RMSEA=0.064, SRMR=0.024; Hu and Bentler, 1999).

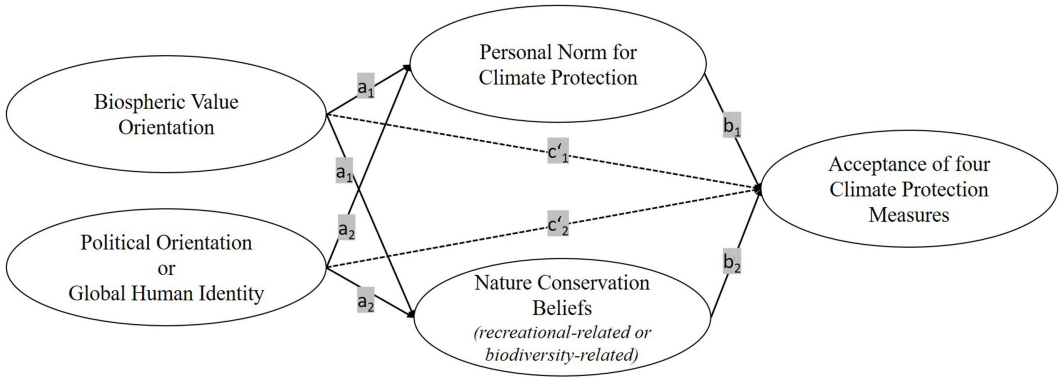

FIGURE 2
Path Diagram for the Mediation Model. a = direct effect of predictor on mediator, b = direct effect of mediator on criterion ($a \times b$ = indirect effect), c' = direct effect of predictor on criterion. The four climate protection measures were: generating energy with wind turbines, generating energy with photovoltaic systems in cities, generating energy with free-field photovoltaic systems, building with wood instead of cement.

2.2.3. Nature conservation beliefs

We measured two different nature conservation beliefs, each referring to a different value orientation. The two beliefs were NCB_recr: "The key task of nature conservation lies in the preservation of human recreational spaces" (based on altruistic values: recreational value of nature) and NCB_biodiv: "The key task of nature conservation is to safeguard the biodiversity of animals and plants" (based on biospheric value orientation/conservation as a value itself). These beliefs were measured with single items[5] that were answered on a 5-point Likert scale (1 = completely disagree; 5 = completely agree).

2.2.4. Global human identity

To measure participants' global human identity, we developed a short version of the nine-item IWAH scale (identification with all humanity), originally developed by McFarland et al. (2012) and translated into a German version by Loy et al. (2022) and Reese et al. (2015). The short version was slightly modified and consisted of four items ("I feel connected to people all over the world"; "I think of people all over the world as 'we'"; "I feel in solidarity with people all over the world"; "I want to be a responsible member of the global community"), which were scored on a 7-point Likert scale (1 = does not apply at all; 7 = fully applies). The scale was highly reliable ($\omega = 0.93$), and the unidimensional CFA yielded appropriate standardized factor loadings ($0.77 \leq \lambda \leq 0.91$; MLR estimation) as well as fit indices [robust CFI = 0.999, robust RMSEA = 0.045, SRMR = 0.006; (Hu and Bentler, 1999)].

2.2.5. Political orientation

Participants' political orientation was measured with a left–right self-placement scale consisting of only a single item ("Many people use the terms 'left' and 'right' when referring to different political attitudes. When you think about your political views, where would you rank those views on this scale?") on which they could rank themselves on a scale ranging from 1 (left) to 10 (right). This measure allowed respondents to make a classification intuitively and without prior expertise. Even if using a simplified dualism left open what the respondents associated with the terms left and right, studies have shown that most respondents are able to locate both themselves and political parties on the left–right scale (Mair, 2007). This scale is well established for the use on German samples: It is regularly used in election research for Germany, and in political surveys, such as the German General Social Survey (ALLBUS) (Breyer, 2015).

2.2.6. Acceptance of climate protection measures

To identify potential conflicts between nature protection and climate protection, participants were asked for their acceptance of four different climate action measures. These were selected because of their potential to illuminate the conflict between nature protection and climate protection: (1) Generating energy with wind turbines, (2) Generating energy with photovoltaic systems in cities (e.g., photovoltaic systems on roofs), (3) Generating energy with free-field photovoltaic systems (large areas with photovoltaic systems), and (4) Building with wood instead of cement. These four items measured participants' attitude toward each particular strategy on a 5-point Likert scale (1 = completely disagree; 5 = completely agree). Item 2 plays a special role here, as photovoltaic installations in cities are not associated with landscape-altering effects (recreational dimension) and also do not have a clear direct impact on biodiversity (biodiversity dimension). Whether Item 4 is connected to having an impact on biodiversity will largely depend on whether people are aware of the associated forestry measures.

3. Results

We conducted the main analysis with R version 4.0.3 (R Core Team, 2020) and the following R-packages: dplyr (Wickham et al.,

5 Initially, we included nine items in the survey to measure NCB. After extensive analyses of possible factor structures underlying these items and excluding some items, no model showed sufficient psychometric properties. Furthermore, the hypothesized factor structure yielded computational problems, indicating an inadequate item-factor configuration. Thus, we decided to use two items as "marker variables" that represented the two beliefs best in our eyes.

2021), EFAtools (Steiner and Grieder, 2020), lavaan (Rosseel, 2012), MVN (Korkmaz et al., 2014), nortest (Gross and Ligges, 2015), pastecs (Grosjean and Ibanez, 2018), psych (Revelle, 2020), semhelpinghands (Cheung, 2023), and utils (R Core Team, 2020). All R scripts are available from XY upon request. We used IBM SPSS Statistics 27 (IBM Corporation, 2020) to prepare the data.

First, we computed basic descriptive and bivariate statistics. Next, we tested structural equation models (SEM) to establish the predictor structure of the CPM which were used as criteria. Modelling the predictor structure, we chose a path configuration that is both in line with theoretical assumptions and the intention to preliminarily investigate an intrapersonal conflict (Gunzler et al., 2013; Danner et al., 2015). Based on previous research on the relation between personal norms and values (e.g., Joireman and Liu, 2014; van der Werff and Steg, 2016; Wynveen and Sutton, 2017), we hypothesized that broad, fundamental, and comparatively stable concepts such as biospheric values and political orientations inform the development of more specific psychological constructs such as personal norms and beliefs. Furthermore, we specifically operationalized the NCB to be justified by different values (biospheric and anthropocentric values). Hence, PN and NCB were assumed to be mediators of BV and PO or GHI. To obtain first evidence of a potential conflict between climate protection orientation and nature protection orientation, the CPM were directly regressed on PN and both NCB (potentially yielding contrary regression coefficients) while controlling for the influence of BV and PO or GHI. Figure 2 provides an overview of the corresponding path diagram. We estimated a total of eight SEMs in which PN and NCBs both mediated the effects of BV and either PO or GHI (only one of the two constructs was used as the predictor per SEM) on the four different CPM items.

A simple mediation model with a predictor X whose effect on a criterion Y is mediated by a third variable (the mediator M) can be described by three regression models. First, the total effect of the predictor X is estimated by regressing the criterion Y on the predictor X (Equation 1). Then, the mediator M is regressed on the predictor X (Equation 2), while the criterion Y is simultaneously regressed on the predictor X and the mediator M (Equation 3). In the equations i represents the intercept of the model and e the error.

$$Y_i = i_{Y.X} + cX_i + e_{Y.X_i} \quad (1)$$

$$M_i = i_{M.X} + aX_i + e_{M.X_i} \quad (2)$$

$$Y_i = i_{Y.MX} + bM_i + c'X_i + e_{Y.MX_i} \quad (3)$$

We refrained from interpreting the total effect c from Equation (1) as it can be misleading and as its significance is not indicative of the existence a mediation effect (Zhao et al., 2010; Rucker et al., 2011; Igartua and Hayes, 2021). The effect of predictor X on criterion Y consists of two additive paths ($c = c' + ab$). The indirect effect of X on Y through mediator M equals the product of a and b from Equations (2, 3). The second path is the direct effect c' of X on Y controlled for M. Thus, c' captures the effects independent of the mediation. When assessing whether a mediation is significant, the pattern of c and c' is irrelevant (Igartua and Hayes, 2021). We only focused on the indirect effect ab (how X affects Y by affecting M) and assumed a mediation when this product was significant and when the confidence interval did not include zero. The previous distinction into full and partial mediation advocated by Baron and Kenny (1986) will not be considered as it relies on the interpretation of the pattern of c and c'. Nevertheless, a significant indirect effect c' can indicate the existence of additional mediators (Zhao et al., 2010).

The parameters of these SEMs were estimated with a Maximum Likelihood (ML) algorithm combined with the bootstrapping of 1,000 samples (Igartua and Hayes, 2021).To estimate the confidence intervals (CI) of the parameters and account for the non-normal distribution of the indirect effects in a mediation analysis, we computed the 95% bootstrap percentile CI. For the single-item measures, a latent variable was defined with the item loading on it having an unstandardized error variance of 0.10 (reflecting a "scale" reliability of 0.90).

In the description of the results, we refrained from using causal language, as our cross-sectional design does not allow the interpretation of the found relations between the variables as causal mechanisms.

3.1. Descriptive and bivariate statistics

Supplementary Table A1 provides an overview of the item-level descriptive statistics. Both tests of univariate normality – the Shapiro–Wilk test and the Shapiro-Francia test – indicated a deviation from normality for all items (Shapiro and Wilk, 1965; Royston, 1983). Furthermore, the item groups that formed the scales for measuring PN, BV, and GHI were not multivariate normally distributed (Mardia, 1970; Henze and Zirkler, 1990); see Suppelementary Tables A3–A6 for the respective test statistics.

The means, medians, standard deviations, skewness, and kurtosis of the manifest factor scores (based on the mean of the items) and single-item measures can be found in Supplementary Table A2. Again, the Shapiro–Wilk and the Shapiro-Francia tests of univariate normality indicated that none of the manifest factor scores or single-item measures were normally distributed (see Suppelementary Tables A3–A6). The means of all constructs were significantly[6] greater than the scale midpoints except for the mean of recreational NCB ($M = 2.98$). In particular, the four CBM measures were highly skewed toward high acceptance ($M_{Wind\ Turbines} = 4.19$; $M_{Photovoltaic\ (city)} = 4.55$; $M_{Photovoltaic\ (free\text{-}field)} = 4.18$; $M_{Building\ with\ Wood} = 3.91$), thus indicating that the participants who knew about these measures also accepted them to a large degree. Furthermore, the means of both GHI ($M = 4.61$) and PO ($M = 5.93$) were slightly skewed toward higher values, thus reflecting that our sample was more politically oriented toward the left and tended to identify with all of humankind.

The Pearson correlation coefficients can be found in Table 1. Applying the common effect size cut-offs for Pearson correlation coefficients, the four CPM items were correlated to a small or medium degree ($0.13 \leq r \leq 0.38$) with all constructs but recreational NCB ($-0.07 \leq r \leq -0.01$). Furthermore, the correlation between the two

6 We conducted one-sample t-tests with a right-tailed alternative hypothesis ($\mu > \mu_0$).

TABLE 1 Pearson correlation coefficients based on manifest scale scores.

	BV	NCB		GHI	PO		CPM		
		Recreational	Biodiversity			WT	PV (city)	PV (field)	BW
PN	0.56*** (1427)	0.09*** (1427)	0.34*** (1427)	0.60*** (1427)	0.30*** (1297)	0.38*** (1280)	0.32*** (1219)	0.29*** (1042)	0.27*** (1093)
BV		0.15*** (1427)	0.49*** (1427)	0.48*** (1427)	0.16*** (1297)	0.22*** (1280)	0.29*** (1219)	0.18*** (1042)	0.26*** (1093)
NCBs									
NCB (recreational)			0.06* (1427)	0.16*** (1427)	−0.07* (1297)	−0.05 (1280)	−0.01 (1219)	−0.02 (1042)	−07* (1093)
NCB (biodiversity)				0.28*** (1427)	0.13*** (1297)	0.17*** (1280)	0.29*** (1219)	0.17*** (1042)	0.18*** (1093)
GHI					0.28*** (1297)	0.26*** (1280)	0.25*** (1219)	0.20*** (1042)	0.26*** (1093)
PO						0.22*** (1182)	0.14*** (1134)	0.16*** (981)	0.13*** (1014)
CPMs									
Wind Turbines							0.46*** (1177)	0.52*** (995)	0.20*** (1033)
Photovoltaic (city)								0.49*** (1000)	0.24*** (999)
Photovoltaic (free-field)									0.23*** (899)

PN, Personal Norm for Climate Protection; BV, Biospheric Value Orientation; NCBs, Nature conservation beliefs; GHI, Global Human Identity; PO, Political Orientation; CPMs, Acceptance of Climate Protection Measures, WT, Generating energy with wind turbines, PV (city), Generating energy with photovoltaic systems in cities, PV (field), Generating energy with free-field photovoltaic systems; BW, Building with wood instead of cement. Pairwise deletion was applied. *n* in parentheses. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

NCB measures was rather small ($r = 0.06$), thus supporting the assumption that these beliefs refer to different value orientations (biospheric versus altruistic value orientation). The correlations between biodiversity-related NCB and PN ($r = 0.34$), BV ($r = 0.49$), PO ($r = 0.13$), as well as GHI ($r = 0.28$) were significantly[7] larger than the correlations between recreation-related NCB and these constructs ($r = 0.09$, $r = 0.15$, $r = -0.07$, $r = 0.16$). The acceptance of generating energy with photovoltaic systems in cities and of building with wood instead of cement were also significantly more strongly associated with GHI ($r_{Photovoltaic\ (city)} = 0.25$, $r_{Building\ with\ Wood} = 0.26$) than with PO ($r_{Photovoltaic\ (city)} = 0.14$, $r_{Building\ with\ Wood} = 0.13$), whereas the difference between the correlations was not significant for the acceptance of generating energy with wind turbines or generating energy with free-field photovoltaic systems.

3.2. Mediation analyses

The eight SEMs that we computed to test our mediation hypotheses all showed good to excellent model fit (CFI ≥ 0.967, RMSEA ≤0.072, SRMR ≤0.044; Hu and Bentler, 1999) despite the significant χ^2 test statistics oversensitive in large samples; (Bentler and Bonett, 1980). Table 2 provides an overview of the fit indices.

As we achieved a model fit that was sufficient for the further interpretation of the models, we now turn to the different model paths. Tables 3, 4 present the path coefficients and R^2 values for all SEMs, while Figure 3 and Table 5 contain the overall interpretations of the models.

3.3. Acceptance of wind turbines

Turning first to the model with BV and PO as the predictors and wind turbines as the criterion, PN mediated the relationship between BV and the acceptance of wind turbines. A higher level of BV was positively associated with PN, whereas PN had a positive relationship with acceptance. This relationship was the same for PO (being more politically oriented to the left was positively associated with PN) with the difference that PO was still a significant predictor of acceptance when the effect of PN was controlled for. Furthermore, we found that recreational NCB mediated both BV and PO's relationships with the acceptance of wind turbines. A higher BV was associated with a higher recreational NCB, which was negatively associated with the acceptance of wind turbines. Also, being more politically oriented toward the right was positively associated with recreational NCB, whereas recreational NCB had a negative relationship with the acceptance of wind turbines. We did not find any mediating effect of biodiversity-related NCB in this model.

7 The significance of the difference between the correlations was tested with Pearson and Filon's *z* (Pearson and Filon, 1898; Raghunathan et al., 1996).

TABLE 2 Fit Indices for the eight structural equation models for testing the mediation hypotheses.

Model	CFI	RMSEA	SRMR	BIC	χ^2 (df)
Criterion: CPM Wind Turbines					
With Political Orientation ($n = 1,182$)	0.981	0.059	0.028	34,306	137.1*** (27)
With Global Human Identity ($n = 1,280$)	0.969	0.069	0.044	47,103	398.5*** (56)
Criterion: CPM Photovoltaic (city)					
With Political Orientation ($n = 1,134$)	0.975	0.068	0.031	32,067	168.3*** (27)
With Global Human Identity ($n = 1,219$)	0.967	0.072	0.043	43,831	408.2*** (56)
Criterion: CPM Photovoltaic (free-field)					
With Political Orientation ($n = 981$)	0.982	0.056	0.027	28,504	111.0*** (27)
With Global Human Identity ($n = 1,042$)	0.967	0.071	0.042	38,314	348.4*** (56)
Criterion: CPM Building with wood					
With Political Orientation ($n = 1,014$)	0.985	0.051	0.024	29,272	99.2*** (27)
With Global Human Identity ($n = 1,093$)	0.972	0.065	0.041	39,898	317.5*** (56)

$\chi^2 = \chi^2$ test statistic, df, Degrees of Freedom; CFI, Comparative Fit Index; RMSEA, Root Mean Square Error of Approximation; SRMR, Standardized Root Mean Square Residual; BIC, Bayesian Information Criterion; CPM, Climate Protection Measures. *** $p < 0.001$. Maximum Likelihood was applied.

The model with BV and GHI as predictors yielded a similar pattern with PN mediating both the relationship between BV and the acceptance of wind turbines and the relationship between GHI and acceptance (same associations as in the model with PO). We found no mediating effect of recreational NCB on the association between BV and the acceptance of wind turbines, but recreational NCB mediated the relationship between GHI and acceptance. For participants with a higher GHI, it was more important to protect nature for recreational reasons, and this higher level of recreational NCB had a negative association with the acceptance of wind turbines. Again, we found no mediating effect of biodiversity-related NCB.

The R^2 (in our case, the amount of variance explained in the CPM item) was 0.19 in the model with PO and 0.18 in the model with GHI.

3.4. Acceptance of photovoltaic systems in cities

In the model with BV and PO as the predictors and the acceptance of photovoltaic systems (PVS) in cities as the criterion, we found that PN mediated the relationship between BV and the acceptance of PVS in cities, while the direct relation of BV and PVS in cities was still significant and positive. BV was positively associated with PN, which in turn had a positive relationship with the acceptance of PVS in cities. PN also mediated the relationship between PO and acceptance. By contrast, we found no mediating effect of recreational NCB in this model. Biodiversity-related NCB mediated the relationship between BV and the acceptance of PVS in cities but not the relationship between PO and acceptance. A higher BV was positively associated with the belief that nature conservation should secure biodiversity, and higher biodiversity-related NCB was associated with a higher acceptance of PVS in cities.

We found the same mediating effects in the model with BV and GHI as the predictors (without a significant direct relation of BV). To elaborate on the mediation involving GHI, GHI was positively associated with PN, which in turn had a positive effect on the acceptance of PVS in cities.

The R^2 was 0.21 in the model with PO and 0.20 in the model with GHI.

3.5. Acceptance of free-field photovoltaic systems

In the model with BV and PO as the predictors, we found that PN had a mediating effect on BV and PO's relationships with the acceptance of free-field PVS. A higher level of BV and being more politically oriented to the left were positively associated with PN, which in turn had a positive relationship with acceptance. We found no mediating effect of recreational NCB, but biodiversity-related NCB mediated the relationships between BV and the acceptance of PVS on free fields. BV had a positive relationship with biodiversity-related NCB, which in turn had a positive association with the acceptance of free-field PVS.

Again, the model with BV and GHI as the predictors yielded the same mediation effects. A higher level of GHI was positively related to PN, which had a positive association with the acceptance of free-field PVS.

The R^2 was 0.11 in the model with PO and 0.10 in the model with GHI.

3.6. Acceptance of building with wood instead of cement

We found that PN mediated BV and PO's relationships with the acceptance of building with wood instead of cement. Whereas having a higher BV and being more politically oriented to the left were positively related to PN, a higher PN was positively associated with the acceptance of building with wood instead of cement. We found no other mediating effects in the model.

The same mediation pattern applied to the model with BV and GHI as the predictors. A higher GHI had a positive relationship with PN, and a higher PN was positively associated with the acceptance of building with wood instead of cement.

TABLE 3 Structural equation models for testing the mediation hypotheses with biospheric value orientation (BV) and political orientation (PO) as predictors.

Model	β (95%-CI)					Completely Standardized Indirect Effect (95%-CI) (BV→)	Completely Standardized Indirect Effect (95%-CI) (PO→)	R^2
	a_1 (BV→)	a_2 (PO→)	b	c′	c			
CPM Wind Turbines (n = 1,182)								0.19
BV				0.03 (−0.09; 0.13)	0.24*** (0.16; 0.31)			
PO				0.10** (0.03; 0.15)	0.18*** (0.12; 0.24)			
PN	0.59*** (0.54; 0.63)	0.21*** (0.17; 0.26)	0.36*** (0.27; 0.45)			0.21*** (0.16; 0.26)	0.08*** (0.05;0.11)	
NCB (recreational)	0.15*** (0.08; 0.22)	−0.10** (−0.16; −0.04)	−0.10** (−0.16; −0.04)			−0.02** (−0.03; −0.01)	0.01* (0.003;0.02)	
NCB (biodiversity)	0.53*** (0.47; 0.58)	0.03 (−0.03; 0.09)	0.04 (−0.05; 0.13)			0.02 (−0.03; 0.07)	0.001 (−0.003; 0.01)	
CPM Photovoltaic (city) (n = 1,134)								0.21
BV				0.13* (0.004; 0.27)	0.36*** (0.28; 0.43)			
PO				0.04 (−0.03; 0.10)	0.09** (0.03; 0.16)			
PN	0.59*** (0.54; 0.64)	0.21*** (0.17; 0.26)	0.20*** (0.09; 0.30)			0.12*** (0.05; 0.18)	0.04** (0.02; 0.07)	
NCB (recreational)	0.16*** (0.09; −22)	−0.09** (−0.15; −0.03)	−0.06 (−0.12;-0.004)			−0.01 (−0.02; −0.001)	0.01 (0.00; 0.01)	
NCB (biodiversity)	0.54*** (0.48; 0.59)	0.04 (−0.02; 0.10)	0.21*** (0.12; 0.30)			0.11*** (0.07; 0.16)	0.01 (−0.004; 0.02)	
CPM Photovoltaic (free-field) (n = 981)								0.11
BV				−0.02 (−0.16; 0.10)	0.18*** (0.10; 0.25)			
PO				0.07 (−0.003; 0.13)	0.14*** (0.07; 0.20)			
PN	0.59*** (0.54; 0.64)	0.23*** (0.17; 0.28)	0.27*** (0.16; 0.38)			0.16*** (0.09; 0.23)	0.06*** (0.03; 0.09)	
NCB (recreational)	0.15*** (0.08; 0.23)	−0.10** (−0.17; −0.03)	−0.06 (−0.12; 0.01)			−0.01 (−0.02; 0.002)	0.01 (−0.001; 0.02)	
NCB (biodiversity)	0.54*** (0.47; 0.60)	0.02 (−0.04; 0.09)	0.11* (0.01; 0.20)			0.06* (0.01; 0.11)	0.002 (−0.01; 0.01)	
CPM Building with wood (n = 1,014)								0.11

(Continued)

TABLE 3 (Continued)

Model	β (95%-CI)					Completely Standardized Indirect Effect (95%-CI) (BV→)	Completely Standardized Indirect Effect (95%-CI) (PO→)	R^2
	a_1 (BV→)	a_2 (PO→)	b	c′	c			
BV				0.14* (0.03; 0.26)	0.27*** (0.20; 0.35)			
PO				0.05 (−0.01; 0.11)	0.09** (0.02; 0.15)			
PN	0.60*** (0.54; 0.65)	0.20*** (0.15; 0.25)	0.17** (0.06; 0.27)			0.10** (0.04; 0.16)	0.03** (0.01; 0.06)	
NCB (recreational)	0.14*** (0.08; 0.22)	−0.10** (−0.16; −0.04)	0.04 (−0.03; 0.11)			0.01 (−0.004; 0.02)	−0.004 (−0.01; 0.003)	
NCB (biodiversity)	0.51*** (0.45; 0.57)	0.06* (0.001; 0.12)	0.05 (−0.04; 0.14)			0.03 (−0.02; 0.07)	0.003 (−0.003; 0.01)	

β, standardized regression coefficient; CI, confidence interval, R^2, amount of variance explained in the criterion by all predictors and mediators, **a**, effect of predictor on mediator, **b**, effect of mediator on criterion, **c′**, direct effect of predictor on criterion, **c**, total effect of predictor on criterion, PN, Personal Norm for Climate Protection, BV, Biospheric Value Orientation, NCB, Nature Conservation Belief, PO, Political Orientation, CPM, Acceptance of Climate Protection Measure. Maximum Likelihood estimation and bootstrapping were applied.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The R^2 was 0.11 in the model with PO and 0.12 in the model with GHI.

4. Discussion

In the study at hand, we were interested in investigating possible value-based conflicts between motives for nature conservation and motives for climate protection regarding the acceptance of climate protection measures. It was expected that these potential conflicts might not manifest themselves in the same way for different climate protection measures. Furthermore, the study was aimed at illuminating possible interrelationships between political orientation (and human identity) and nature-conservation-related and climate-protection-related beliefs and value orientations. In doing so, we wanted to shed light on possible underlying conflicts of interest and value-based conflicts, because these conflicts, which are to be assessed as more or less negotiable, would represent a major problem for the acceptance of political measures of climate protection, as well as for the acceptance of nature conservation concerns. First, the results showed that there were substantial similarities between nature conservation beliefs justified by biospheric value orientation (protecting biodiversity) and values and norms relevant for climate protection: There were strong intercorrelations between personal norm, biospheric values, and conservation beliefs that are associated with protecting biodiversity. For conservation beliefs justified by altruistic or egoistic value orientation (preservation of recreational value), the correlations with personal norm and biospheric values were still significant but notably lower. A similar picture emerged for correlations with the acceptance of the four climate protection measures we considered. Again, there were significant positive correlations between personal norm, biospheric values, and biodiversity-related nature conservation beliefs, whereas the correlations between recreational nature conservation beliefs were negatively related or not related at all to the acceptance of the four climate protection measures. In conclusion, there seem to be no substantial value-based conflicts between nature conservation aimed at preserving biodiversity and protecting the climate. In order to increase the acceptance of climate-protection measures, the rather anthropocentric argument that we should preserve the recreational value of nature can be interpreted as a hint toward a conflict of interest. The importance of the expansion of renewable energies and climate protection for the preservation of people's livelihoods could be emphasized more.

Second, there was a significant correlation between political orientation and the acceptance of all four climate protection measures (the more left-oriented a person's political orientation, the higher their acceptance). The same was true for the correlations between global human identity and the acceptance measures, but these correlations were even larger. Furthermore, political orientation and global human identity showed medium to large positive correlations with biospheric values and personal norm. Interestingly, the correlations between political orientation and the expressions of nature conservation beliefs were more nuanced. With respect to nature conservation with the goal of preserving biodiversity, there was a slight positive correlation, whereas the correlation with nature protection for recreational value was slightly negative. As mentioned above, recreation-oriented conservation beliefs seem to be associated with lower acceptance of climate protection measures. Furthermore, political orientation seems to be important for nature conservation beliefs (the more right-oriented a person's political orientation, the higher their recreation-oriented conservation beliefs). This can be seen as a potential conflict between political orientation and nature conservation beliefs, but this is not the case for biodiversity-oriented nature conservation beliefs. For global human identity, there were significant correlations with both conservation beliefs, but the correlation with the recreation-related conservation belief was larger (a belief that has an anthropocentric rationale), which seems logical since global human identity is about identification with humanity and not with nature.

Third, taking into account the possible interrelationships between political orientation and both nature-conservation-related and climate-protection-related beliefs and value orientations with respect

TABLE 4 Structural equation models for testing the mediation hypotheses with biospheric value orientation (BV) and global human identity (GHI) as predictors.

Model	β (95%-CI)					Completely Standardized Indirect Effect (95%-CI) (BV→)	Completely Standardized Indirect Effect (95%-CI) (GHI→)	R^2
	a_1 (BV→)	a_2 (GHI→)	b	c′	c			
CPM Wind Turbines (n = 1,280)								0.18
BV				0.004 (−0.11; 0.11)	0.18*** (0.09; 0.27)			
GHI				0.05 (−0.03; 0.13)	0.19*** (0.10; 0.27)			
PN	0.41*** (0.35; 0.47)	0.43*** (0.36; 0.47)	0.37*** (0.28; 0.46)			0.15*** (0.11; 0.20)	0.16*** (0.11; 0.21)	
NCB (recreational)	0.07 (−0.001; 0.15)	0.13** (0.06; 0.20)	−0.11*** (−0.16; −0.05)			−0.01 (−0.02; 0.00)	−0.01* (−0.03; −0.004)	
NCB (biodiversity)	0.56*** (0.48; 0.63)	−0.01 (−0.09; 0.06)	0.06 (−0.02; 0.14)			0.03 (−0.01; 0.08)	−0.001 (−0.01; 0.004)	
CPM Photovoltaic (city) (n = 1,219)								0.20
BV				0.12 (−0.004; 0.26)	0.32*** (0.23; 0.41)			
GHI				0.02 (−0.06; 0.11)	0.10* (0.02; 0.19)			
PN	0.41*** (0.35; 0.48)	0.43*** (0.36; 0.49)	0.21*** (0.09; 0.32)			0.09*** (0.04; 0.13)	0.09** (0.04; 0.14)	
NCB (recreational)	0.08* (0.003; 0.15)	0.13** (0.06; 0.21)	−0.06* (−0.11; −0.01)			−0.01 (−0.01; 0.00)	−0.01 (−0.02; −0.001)	
NCB (biodiversity)	0.57*** (0.49; 0.64)	−0.02 (−0.09; 0.06)	0.20*** (0.12; 0.28)			0.11*** (0.07; 0.17)	−0.003 (−0.02; 0.01)	
CPM Photovolt. (free-field) (n = 1,042)								0.10
BV				−0.02 (−0.14; 0.11)	0.15** (0.05; 0.25)			
GHI				0.02 (−0.08; 0.12)	0.13** (0.03; 0.22)			
PN	0.42*** (0.35; 0.48)	0.42*** (0.35; 0.49)	0.28*** (0.17; 0.39)			0.12*** (0.07; 0.17)	0.12*** (0.07; 0.17)	
NCB (recreational)	0.06 (−0.02; 0.14)	0.15*** (0.07; 0.22)	−0.05 (−0.12; 0.02)			−0.003 (−0.01; 0.002)	−0.01 (−0.02; 0.002)	
NCB (biodiversity)	0.56*** (0.47; 0.63)	−0.01 (−0.09; 0.06)	0.10* (0.01; 0.19)			0.06* (0.003; 0.11)	−0.001 (−0.01; 0.01)	
CPM Building with wood (n = 1,093)								0.12
BV				0.11 (−0.01; 0.22)	0.20*** (0.11; 0.29)			

(Continued)

TABLE 4 (Continued)

Model	β (95%-CI)					Completely Standardized Indirect Effect (95%-CI) (BV→)	Completely Standardized Indirect Effect (95%-CI) (GHI→)	R^2
	a_1 (BV→)	a_2 (GHI→)	b	c′	c			
GHI				0.11* (0.01; 0.20)	0.17*** (0.08; 0.25)			
PN	0.43*** (0.36; 0.49)	0.40*** (0.33; 0.47)	0.13* (0.03; 0.24)			0.06* (0.01; 0.10)	0.05* (0.01; 0.10)	
NCB (recreational)	0.05 (−0.02; 0.13)	0.13** (0.06; 0.21)	0.04 (−0.03; 0.10)			0.002 (−0.002; 0.01)	0.01 (−0.004; 0.02)	
NCB (biodiversity)	0.52*** (0.44; 0.59)	0.02 (−0.05; 0.10)	0.07 (−0.02; 0.15)			0.03 (−0.01; 0.08)	0.001 (−0.01; 0.01)	

β, standardized regression coefficient; CI, confidence interval; R^2, amount of variance explained in the criterion by all predictors and mediators, **a**, effect of predictor on mediator; **b**, effect of mediator on criterion; **c′**, direct effect of predictor on criterion; **c**, total effect of predictor on criterion; PN, Personal Norm for Climate Protection; BV, Biospheric Value Orientation; NCB, Nature Conservation Belief; GHI, Global Human Identity; CPM, Acceptance of Climate Protection Measure. Maximum Likelihood estimation and bootstrapping were applied.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

to the acceptance of climate protection measures in more detail, we tested structural equation models for each of the four climate protection measures. For all of the four measures, personal norm mediated the relationships between biospheric values and acceptance of the climate protection measures. Likewise, personal norm also mediated the influence of political orientation on the acceptance of the four measures. If global human identity was included as a predictor instead of political orientation, personal norm also mediated the associations with the acceptance of all four measures. These findings support the key role of personal norm in this context.

The results were particularly interesting with regard to two measures, namely, the acceptance of wind turbines and building with wood. Whereas biodiversity-related nature conservation beliefs mediated the influence of biosphere values on the acceptance of photovoltaic systems in cities as well as free-field photovoltaic systems, recreation-related nature conservation beliefs mediated this relationship for the acceptance of wind turbines, but biodiversity-related nature conservation beliefs were not relevant. As already stated above, the aspect of recreation seems to play a specific role when it comes to the acceptance of wind turbines.

The mediation analyses in which building with wood was a criterion showed no mediating effects of either of the nature conservation beliefs. This result could be interpreted as an indication that the respondents might not have reflected on the consequences of this measure for future forest management and use.

TABLE 5 Overview of the results for the mediation hypotheses with biospheric value orientation (BV) and global human identity (GHI).

Criterion	Mediator	Predictor	
		BV	GHI
CPM wind turbines	PN	mediation	mediation
	NCB recreational	no mediation	mediation
	NCB biodiversity	no mediation	no mediation
CPM Photovoltaic (city)	PN	mediation	mediation
	NCB recreational	no mediation	no mediation
	NCB biodiversity	mediation	no mediation
CPM Photovoltaic (free-field)	PN	mediation	mediation
	NCB recreational	no mediation	no mediation
	NCB biodiversity	mediation	no mediation
CPM building with wood	PN	mediation	mediation
	NCB recreational	no mediation	no mediation
	NCB biodiversity	no mediation	no mediation

PN, Personal Norm for Climate Protection, BV, Biospheric Value Orientation, NCB, Nature conservation beliefs, GHI, Global Human Identity, CPM, Acceptance of Climate Protection Measure.

5. Limitations and further research

The findings presented and discussed here are to be considered embedded in their local, socio-political context. Our sample was representative of the German population. This is certainly a limitation of the study, as Germany is a very densely populated country, which poses a particular challenge for measures with an impact on land use. However, we assume that the main findings reported here might be of relevance to large parts of Europe and also to the US. With regard to the discussion of possible risks of the instrumentalization of conservation narratives by political groups, caution is certainly required; here, for example, German conservation history and its historical instrumentalization by right-wing nationalists play a special role.

The study at hand does not provide the testing of a full-fledged model and does therefore not claim to fully explain the socio-political acceptance of climate protection measures. Instead, we believe that the results might provide indications for a constructive management of climate protection measures and nature conservation. Even though the study focuses specifically on potential conflicts, there are still some limitations.

Regarding the measurement instruments we used, only biospheric values were collected. Not taking all value orientations into account represents a clear limitation of the study presented here. Since the major

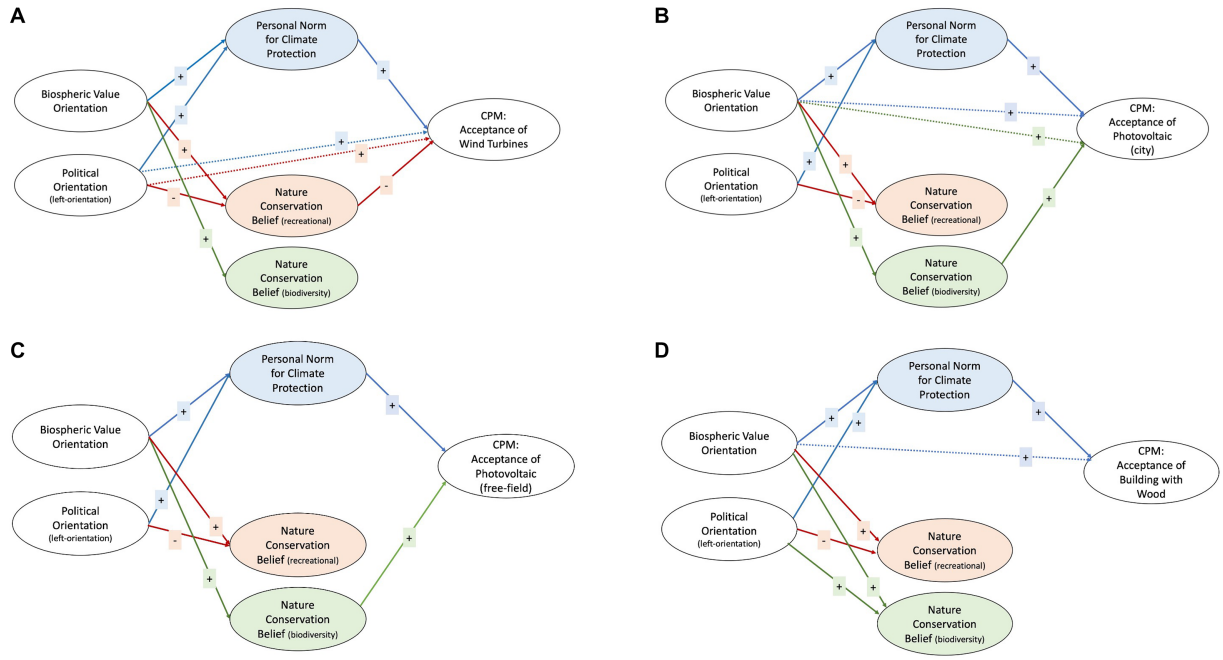

FIGURE 3
Overview of the Results for the Mediation Hypotheses with Political Orientation. Note. **(A)** Wind turbines, **(B)** Photovoltaic (city), **(C)** Photovoltaic (free-field), and **(D)** Building with Wood.

risk of conflict is expected to arise from a contradiction between biospheric values and climate protection motives, we nevertheless believe that the present findings can make a valuable contribution to the further analysis in this domain and recommend that future studies also include egoistic and altruistic values. Furthermore, we used single items to measure nature conservation beliefs due to the insufficient psychometric properties of the original nine items. Sufficient scales should be developed for future research. It must be mentioned that the correlation-based analyses do not allow causal conclusions. Experimental research designs would be needed to analyze the causal relationships more systematically. Mediation models should be tested with longitudinal data or experimental interventions as they model causal mechanisms. Thus, the results from the mediation analyses in this study should be interpreted as preliminary evidence against a potential intrapersonal conflict between climate protection orientation and nature conservation orientation grounded in biospheric values. Further research based on experimental designs could continue to shed light on potential conflicts by systematically varying the specific impacts and constraints of climate protection measures on nature and biodiversity.

We see a need for further research, especially regarding a more differentiated analysis of political orientation. In the present study, important insights were gained, also regarding possible ties with the concept of global human identity. In fact, this relationship does not seem to be particularly close, as global human identity seems to be linked more to personal ecological norms than to political orientation.

At the same time, it is evident that it is worthwhile to use more differentiated instruments to measure political orientation in future studies to better understand the interplay between political orientation, nature conservation beliefs, and the acceptance of climate protection measures. To further test the findings obtained here, specific populations, such as members of nature conservation associations or right-wing supporters, could be analyzed in more detail in the future.

Recent policy papers and scientific papers have shown a trend toward new topics and technologies such as Carbon Capture (Carbon Capture and Storage, CCS; Carbon Capture and Use, CCU; Cioenergy with Carbon Capture and Storage, BECCS; Direct Air Carbon Capture and Storage, DACCS), use of hydrogen, and Negative Emission Technologies (NET) (Antonini et al., 2020; Borchers et al., 2022). Possible conflicts associated with these upcoming technologies and associated impacts on nature and landscapes may act as drivers – or as barriers – for transformation processes in our society. We hope that our study can inspire further, more differentiated analyses in this field.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AB, EM, MB, and KB contributed to conception and design of the study. AB and LE contributed to the analysis strategies and

interpretation of data and wrote the first draft of the manuscript. KB wrote sections of the manuscript. LE organized the database and performed the statistical analysis. EM supervised the project. All authors provided critical feedback and helped shape the manuscript.

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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 potential conflicts of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1114677/full#supplementary-material

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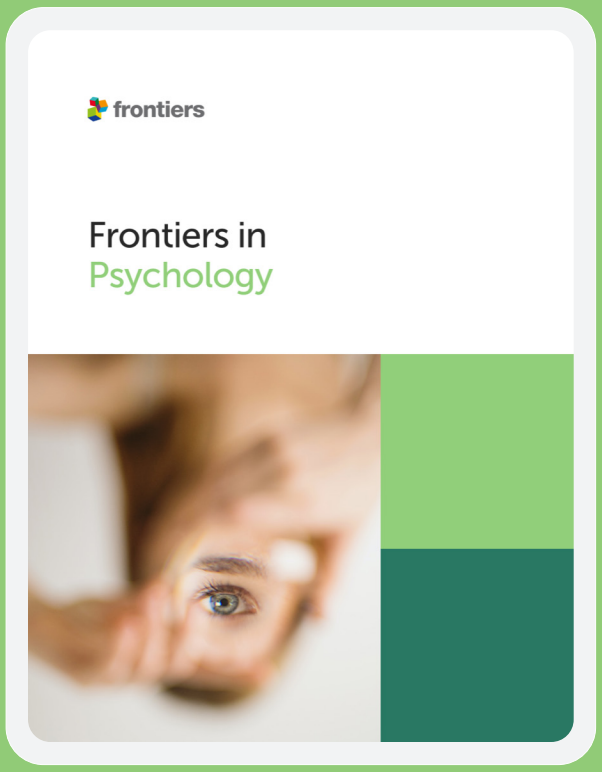

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