Environment, Development and Sustainability
https://doi.org/10.1007/s10668-024-04464-1

Gap between knowledge and action: understanding the consistency of farmers' ecological cognition and green production behavior in Hainan Province, China

Weiqin Li[1] · Dan Qiao[1] · Qinchuan Hao[1] · Yifan Ji[1] · Donghui Chen[1] · Tao Xu[1]

Received: 24 June 2023 / Accepted: 31 December 2023

Abstract

The pivotal role of greening production methods is indispensable in facilitating the sustainable development of China's agricultural sector and its modernization process. Translating farmers' ecological cognition into environmentally conscious production behavior constitutes a fundamental strategy for advancing the green transformation within China's agriculture. However, a recurrent issue arises from an inconsistency between farmers' green production behavior and their ecological cognition. Meanwhile, the current research has fewer studies on the consistency of farmers' cognition and behavior, and more analysis of the logical hierarchical relationship between their influencing factors needs to be done. Based on a field survey of 399 farmers in Hainan Province, this paper first employs descriptive statistics to assess the consistency of farmers' ecological cognition with their green production behavior. Second, this study uses a Logistic model and Interpretative Structural Model (ISM) to empirically analyze the factors influencing such consistency and the internal logical relationships of these factors. The results reveal that merely 28% of farmers exhibit consistency between their ecological cognition and green production practices. Secondly, education level, health status, political capital, household expenditure, planting scales, risk preference, peer influences, policy cognition, social networks, and information acquisition significantly influence this "consistency." Thirdly, the logical hierarchical relationships established via the ISM indicate that peer influences and risk preference are the surface direct factors; policy cognition, information acquisition, social networks, and planting scales are middle indirect factors; education level, political capital, health status, and household expenditure are deep-rooted factors that underpin the entire framework. Given these insights, this study recommends that the government undertake initiatives to reinforce education and training programs, enhance accessibility to information and technical support, and tailor policies to accommodate small-scale farmers. This study endeavor contributes to an enhanced comprehension of the factors influencing the transformation of farmers' ecological cognition into green production behavior, also presenting pragmatic policy proposals to advance sustainable agriculture in China.

Keywords Cognition · Behavior · Consistency · Farmers · Green production

Extended author information available on the last page of the article

1 Introduction

Green production practices are crucial for protecting the ecological environment and achieving sustainable agricultural development (Baah et al., 2021; Chen et al., 2023; Qiao et al., 2022a). Nevertheless, within China, the agricultural development strategy aimed at increasing production and income has resulted in the overutilization of pesticides and chemical fertilizers, which has caused a multitude of severe problems in the rural ecological environment, such as agricultural surface pollution and biodiversity reduction (Cai et al., 2021; Liu et al., 2021; Zhu & Wang, 2021). These problems have seriously hindered the transformation of green production mode in agriculture (Li et al., 2021c; Luo et al., 2023). In response to these extant problems, the Chinese government has introduced an array of policies aimed at fostering green production, such as the 14th Five-Year Plan, which emphasizes the need to strengthen the green orientation of agriculture and promote the green transformation of agricultural production methods. The "Central Document No. 1" issued by the central government also emphasizes the need to strengthen the comprehensive management of agricultural surface pollution and promote green agricultural development. Under the publicity and incentives of the Chinese government, the concept of green and sustainable development has been widely recognized by Chinese farmers, and their level of ecological cognition has significantly increased (Qing et al., 2021; Wang et al., 2021b). Even with this, the actual execution of green production practices remains relatively low among farmers, thereby yielding an inconsistency between the level of ecological cognition and the manifestation of green production behavior (He et al., 2022; Qiu et al., 2022). A study on Chinese farmers shows that 85.31% of them exhibit a heightened ecological cognition, yet merely 34.41% have implemented green production practices (Kuang et al., 2018). The deviation between farmers' cognition and behavior seriously hinders the process of green agricultural development in China. Hence, it is greatly significant for building a strong modernized agricultural power in China to promote the transformation of farmers' ecological cognition into green production behavior.

In recent years, there has been a growing scholarly focus on the consistency between farmers' cognitive aptitude and their tangible actions (Deng et al., 2021; Foguesatto et al., 2020). The cognitive-behavioral theory, a fusion of cognitive theory and behaviorism, suggests that an individual's cognition and behavior are interconnected, displaying a marked degree of consistency. Specifically, social behaviorists believe that cognition is the foundation of behavior, and farmers' level of cognition determines their preferences and determines the occurrence of actual behavior (Yazdanpanah et al., 2015). However, some studies have found that improving individual cognition does not invariably yield corresponding behavioral responses, indicating that there is an inconsistency between farmers' cognition and behavior (Li et al., 2021a; Qiu et al., 2022). Thus, it is of great practical significance and theoretical value to explore the mechanism underlying the consistency between farmers' cognition and behavior.

So far, scholars have extensively studied the relationship between cognition and individual behavior. Some achievements have been made in the analysis of the consistency of farmers' cognition-behavior, mainly focusing on the fields of agricultural green production (Ren et al., 2022), property rights adjustment in the land (Wang et al., 2018), arable land protection (Liu & Zhou, 2018), and habitat governance (Deng et al., 2021). Scholars have found that positive cognition promotes positive behavior (Liu et al., 2014). For instance, Foguesatto et al. (2020) found that green cognition had a significant positive effect on sustainable agricultural behavior, suggesting that increasing farmers' level of green cognition could lead to corresponding green production behavior. Similarly, Wang et al. (2021a) showed that farmers' ecological cognition positively influenced their organic fertilizer application behavior, indicating a consistent relationship between cognition and behavior. However, some scholars have also found that there is an inconsistency between farmers' cognition and behavior. For example, Liu and Zhou (2018) examined farmers' cognitive level and behavioral response levels separately using microdata from 238 farmers and found that farmers' cognition and behavior were inconsistent. Deng et al. (2021) also showed similar inconsistency in farmers' environmental cognition and behavior. Meanwhile, Kuang et al. (2018) conducted regression analysis separately on farmers' ecological cognition and environmental protection behavior using an enhanced regression tree model, and found that the factors affecting cognition and behavior were inconsistent, leading to the conclusion that farmers' cognition and behavior were inconsistent.

The current relevant studies provide a solid foundation for analyzing the consistency of farmers' ecological cognition and green production behavior. However, there are still limitations for further exploration. Firstly, scholars analyzed the deviation of farmers' cognition and behavior separately from two variables of cognition and behavior, without synthetically integrating the variables to carry out the analysis, which leads to the poor reliability of the conclusions. Secondly, the representation of farmers' cognition is single and subjective in some studies. For instance, some studies identified cognitive variables through only one question, while others described cognition based on respondents' subjective evaluation of themselves without objectivity. Thirdly, current research mainly discusses one green production behavior at a time (e.g., organic fertilizer application, biological pesticide application, straw return), while in reality, farmers may engage in multiple green production behaviors simultaneously. Therefore, most current studies need to pay more attention to the comprehensive status of farmers' green production. Finally, scholars often confine their analyses to the influencing factors of ecological cognition and green production behavior, neglecting the hierarchical interrelationships among these influencing factors.

Based on a field survey of 399 farmers in Hainan Province, we first employ descriptive statistics to assess the consistency of farmers' ecological cognition with their green production behavior. Second, we use a Logistic model to empirically analyze the factors influencing such consistency empirically. Third, we use ISM to exploit the internal logical relationships of these factors. The ultimate goal of this study is to provide theoretical support and practical experience to promote the transformation of farmers' cognition into behavior. Compared to extant literature, this study makes several distinctive contributions. Firstly, it synthesizes the consistency between farmers' ecological cognition and green production behavior, further enriching the research on their relationship. Secondly, we establish four questions to measure the level of farmers' ecological cognition and adopt a researcher-led scoring method to improve the accuracy and objectivity of the measurement. Thirdly, we select four types of green production status to represent farmers' green production behavior, providing a more comprehensive characterization. Finally, this paper uses the Logistic model and ISM to analyze the factors affecting farmers' ecological cognition and production behavior and the hierarchical structure among the influencing factors, which enriches the existing research methodology. By providing a comprehensive analysis of the consistency of farmers' ecological cognition and green production behavior, this study can inform policies and practices to promote sustainable agriculture in China. The rest of this article is as follows: Sect. 2 provides a theoretical framework. Section 3 presents a brief overview of the materials and methods. Section 4 presents the results, which include results from the Logistic model and ISM. Finally, Sect. 5 outlines the conclusions and discussion.

2 Theoretical framework

A combination of factors influences farmers' ecological cognition and green production behavior. In this paper, we primarily draw upon the cognitive-behavioral theory as the foundational theoretical framework, while also integrating insights from the theory of farmer behavior, the theory of rational smallholders, and the prospect theory to establish a comprehensive theoretical framework. These theories collectively posit that farmers act as rational economic agents, and whether to translate positive ecological cognition into concrete actions necessitates farmers to consider various factors comprehensively and rationally. This paper focuses on the factors influencing the consistency of farmers' ecological cognition and their green production behavior, including individual factors, family factors, and external factors. The expected effects of each variable on the consistency of farmers' cognition- behavior are as follows:

The unique individual factors of farmers, including gender, age, education level, health status, part-time employment, risk preference, information acquisition, and policy cognition, will exert an impact on the translation of their cognitive level into behavioral decision-making, as posited by the theory of farmers' behavior. Generally, male farmers are more willing to adopt green production than their female counterparts, owing to their greater aptitude for learning new things and accepting novel concepts (Gebre et al., 2019). As farmers age, they are more likely to possess a more accurate understanding and acceptance of knowledge or technology related to green production (Vahmani et al., 2016), which facilitates the transition from cognition to action. Conversely, older farmers may also become less receptive to new ideas, which hinders the transformation of cognition into behavioral practices. Improving the education level of farmers can aid in their comprehension and mastery of knowledge and technology related to green production, consequently bridging the gap between their cognition and behavior (Zhou et al., 2016). Good health status can also enable farmers to adopt green production technologies, as it allows them to implement new agricultural practices (Finger & Möhring, 2022). However, part-time employment may result in a decline in the quality and quantity of agricultural laborers, resulting in an ineffectual business model of agricultural production, thus impeding green production in agriculture (Zhang et al., 2020). Risk-preferring farmers are more inclined to experiment with new technologies and implement green production behavior, while risk-averse farmers may be hesitant to engage in green production to avoid risks, consequently obstructing the transformation of farmers' ecological cognition into green production behavior(Jianjun et al., 2015; Simtowe et al., 2006). Information acquisition is also a crucial factor that impacts farmers' behavioral decisions; the more information farmers acquire, the more likely they are to adopt new behavior (Mohring et al., 2020; Noll et al., 2014; Wilson & Dowlatabadi, 2007), thereby promoting the conversion of cognition into concrete behavioral decisions. Finally, farmers' policy cognition can effectively encourage their adoption of green agricultural technologies, thereby enhancing the likelihood of translating farmers' cognition into production practices (Shang & Yang, 2021). Based on the above analysis, this paper proposes Hypothesis 1: Individual factors of farmers influence the consistency between farmers' ecological cognition and green production behavior.

The theory of rational small farmers believes that family factors of farmers influence the transformation of their cognition into concrete action (Wang & Gu, 2012). Generally, village cadres and civil servants are the driving force behind the popularizing of green production. Therefore, to play an exemplary role, farmers from the households of village cadres and civil servants will be more active in adopting green production behaviors, which also reduces the degree of behavior–cognition deviation (Li et al., 2021b). The planting scales also affect farmers' green production behavior (Qin and Lü, 2020). Planting scales with larger sizes tend to have economies of scale and higher specialization, making it easier to adopt new agricultural technologies and increasing the consistency between cognition and behavior. Additionally, the number of people in the household supporting the family can hinder the adoption of green production technology (Li & Shen, 2021), this is because the higher the number of supporting people in the household, the more factors to be taken into consideration when making decisions, which impedes the consistency between cognition and behavior. The amount of laborers available also affects the ability of farm households to implement green production, as households with a high ratio of agricultural laborers have more laborers available to promote the consistency between cognition and actions (Zhang et al., 2022). Moreover, household expenditure can reflect the economic level of farm households, with higher household expenditure indicating a better economic level and a corresponding increase in expenditure on green production, thus facilitating the consistency between cognition and specific green production behavior. Based on the above analysis, this paper proposes Hypothesis 2: farmers' family factors influence the consistency of their cognition and behavior.

According to Prospect Theory (PT), external factors such as land fragmentation, disaster impacts, peer influences, social networks, and interpersonal trust can significantly impact farmers' decision-making behavior, affecting the consistency between farmers' cognition and behavior. For instance, land fragmentation poses a barrier for farmers to achieve economies of scale, which impedes their ability to engage in green production (Cao et al., 2022). Climate disasters also reduce farmers' green production inputs, increasing the likelihood of inconsistency between their cognition and behavior (Dougherty et al., 2020; Holden & Quiggin, 2017). Furthermore, farmers are often vulnerable to the influence of their peers, leading to weakened effects of cognition on behavior and a higher possibility of deviation from their cognition (Li et al., 2023). Meanwhile, social networks can provide valuable support for farmers to acquire information on green production and promote the adoption of green production technologies (Conley & Udry, 2010; Liu et al., 2018). In addition, interpersonal trust also affects farmers' decision-making, which in turn impacts the consistency of their cognition and behavior(Gao et al., 2019). Therefore, this paper proposes Hypothesis 3: external factors influence the consistency between farmers' ecological cognition and green production behavior.

Based on the above theoretical analysis and research hypothesis, this paper establishes a theoretical framework for analyzing cognitive-behavioral consistency, as shown in Fig. 1.

3 Materials and methods

3.1 Study area

This study area is Hainan Province, a tropical Province located in southernmost China. The principal landmass within Hainan Province is Hainan Island, which is geographically positioned between longitudes 108° 37′–111° 03′ E and latitudes 18° 10′–20° 10′ N. It boasts a total land area spanning 35,400 square kilometers and is located on the edge of the tropical realm. The region is characterized by a tropical monsoon climate, abundant in luminosity and thermal resources, delineating distinctive dry

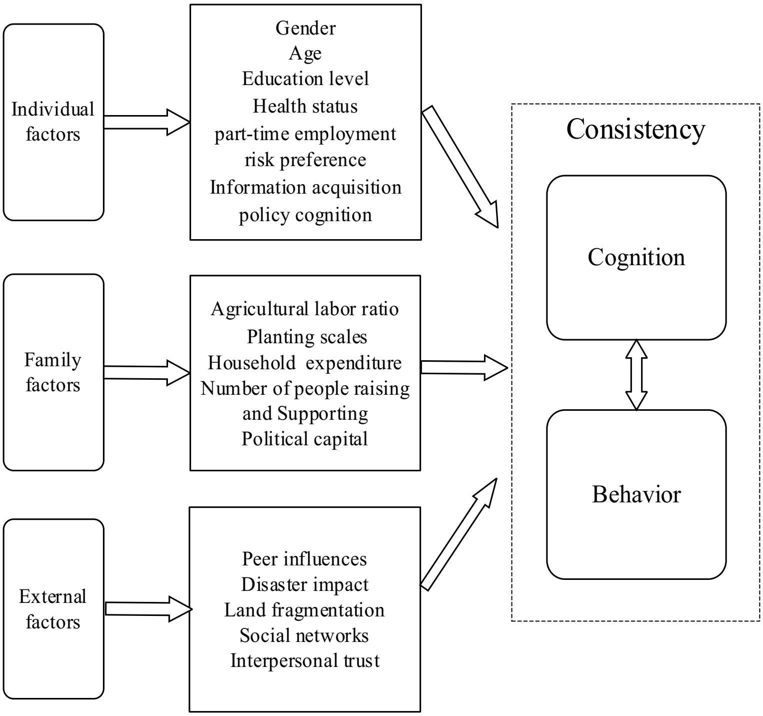

Fig. 1 Theoretical analysis framework of cognitive-behavioral consistency

and rainy seasons. The mean annual temperature hovers at approximately 26.7 °C, while annual precipitation is approximately 1000 mm.

Hainan Province is blessed with unique tropical resources, giving it a significant advantage in tropical characteristic agriculture. Consequently, agriculture has emerged as one of the foundational industries in the province. But, situated apart from mainland China by the Qiongzhou Strait, Hainan Province grapples with higher transportation costs for agricultural products. As a result, Hainan's agriculture predominantly revolves around the cultivation of high-value agricultural commodities, including natural rubber, coconuts, betel nuts, mangoes, and other tropical crops, which require higher inputs of chemical fertilizers and pesticides. This agricultural production paradigm in Hainan has engendered the establishment of a significant scale of tropical crop cultivation, reaping commendable economic benefits. Nonetheless, excessive of use chemical fertilizers and pesticides during agricultural development has sparked a cascade of ecological and environmental issues, such as soil acidification, sloughing and nutrient imbalance, and surface water eutrophication. Against the strategic background of national ecological civilization construction, the agriculture of Hainan Province urgently needs to change from traditional operation patterns to environmentally friendly ones. Therefore, disseminating green production technologies, such as organic fertilizers application and treating straw, among farmers in Hainan Province has become a crucial-initiative for the green transformation and development of Hainan's agriculture.

In recent years, the government of Hainan province has steadfastly adhered to the concept of green development. This commitment is manifested through implementing an array of initiatives, such as high-standard farmland, land strength improvement, field cleaning, straw return to the field, etc., which are geared toward perpetually elevating the quality of arable land, thereby fortifying the foundation of green agricultural development. With the publicity and promotion of the policy, farmers' production cognition and behavior have changed. However, it is noteworthy that there remains a relative need for more scholarly exploration concerning agricultural green production behaviors and ecological cognition within the tropical environs of China.

3.2 Data

Research data were obtained from a field survey conducted from July to August 2021 in Hainan Province. Multistage stratified sampling and random sampling methods were used to select the samples. Four cities, namely Haikou, Dongfang, Qiongzhong, and Lingshui, were selected as sample areas. These areas were selected because of their good representation in terms of regional distribution and economic development levels. These four regions cover the northern, central, and southern parts of Hainan Island in terms of location, with Haikou having a high level of economic development, Dongfang and Lingshui being at a medium level, and Qiongzhong being at a relatively backward economic status.

This study employed a combination of stratified sampling and simple random sampling techniques to ensure the typicality and representativeness of the data. Firstly, 2 to 3 townships were randomly selected from each city based on their agricultural production and operation size. Secondly, 2 to 3 villages were randomly chosen in each township. Finally, 25 to 35 farm households were randomly selected in each village. Thus, 21 villages were chosen in 10 townships, and 666 questionnaires were collected. The questionnaires consisted of information on the basic characteristics of farmers and households, the current situation of agricultural production and operation, the ecological cognition of farmers, and farmers' implementation of green production behavior. To ensure the research quality and improve the credibility of the survey data, all researchers received unified training before conducting the survey. Additionally, interviews were carried out one-on-one with household members, with priority given to the head of the household.

The characteristics of the sample farmers are presented in Table 1. In terms of personal traits, the majority of the farmers are male, comprising 82% of the respondents. 61% of the farmers are 45 years old and above. The education level of farmers is generally low, with 69% having completed only junior high school education or less. Most farmers (92%) are in good health and can care of themselves, with only a tiny percentage having part-time jobs outside the home. Regarding family characteristics, 36% of farm households have family members of village cadres or civil servants. A significant proportion of the households (61%) have less than two people providing care and support. Total household expenditure in 2020 is generally low, with 40% of farmers having a total expenditure of less than 30,000 yuan and 66% of farmers spending less than 50,000 yuan. Additionally, 64% of the households have a planting scale of less than ten mu, while 71% of the household labor force is employed in agriculture. These results suggest that the sample families are mainly engaged in agricultural production, indicating good representativeness.

Table 1 Characteristics of the sample farmers

Variables	Options	*N*	%	Variables	Options	*N*	%
Gender	Male	326	82	Political capital	Yes	145	36
	Female	73	18		No	254	64
Age/years old	< 35	41	10	Number of people raising and supporting/person	≤ 2	243	61
	35~44	117	29		3~4	131	33
	45~54	120	30		≥ 5	25	6
	55~64	85	21				
	≥ 65	36	9	Household expenditure/ten thousand yuan	< 3	158	40
					3~5	98	26
					5~8	84	21
Education level	Primary school and below	68	17		8~10	20	5
	Junior high school	207	52		≥ 10	39	10
	High school or junior college	90	23				
	College and above	34	9	Planting scales/mu	≤ 5	157	39
					5~10	100	25
Health status	General health	31	8		10~20	70	18
	Healthy	368	92		20~30	34	9
					≥ 30	38	10
Agricultural labor ratio	≤ 0.5	74	19				
	0.5~1	41	10	Part-time employment	Yes	178	45
	1	284	71		No	221	55

3.3 Variable settings

3.3.1 Dependent variable

According to the theoretical framework, this paper defines the consistency of farmers' ecological cognition and their green production behavior as the explained variable. If a farmer exhibits a high level of ecological cognition and also implements green production, i.e., there is consistency between the behavior and cognition, the value is 1. Otherwise, if farmers exhibit a high level of ecological cognition, but do not implement green production, i.e., there is no consistency between cognition and behavior, the value is zero. The consistency is assessed in two aspects: farmers' level of ecological cognition and the implementation of green production behavior.

To measure farmers' ecological cognition level, this paper poses four interconnected questions (see Table 2), with each question assigned a score of 0 or 1, and the total score range of the four questions is 0–4. The investigators evaluated the responses to each question and calculated the farmers' ecological cognition level based on the sum of the four questions. Referring to the study by Wang et al. (2021b), the farmers are divided into high and low ecological cognition groups according to the mean value (0.63) of the farmers' ecological cognition level.

In addition, this study evaluates farmers' green production behavior by examining their usage of organic and chemical fertilizers (Chen et al., 2022; Wang et al., 2018), as well as their methods of treating straw and pesticide waste (Mao et al., 2021; Zheng et al., 2020). The surveyors conducted a field survey and asked the farmers questions listed in Table 3 to determine their implementation of green production behavior. A score of 1 was assigned if the farmers had implemented the specified behavior and 0 otherwise. The total score of green production behavior ranged from 0 to 4. Following the research of Wang et al. (2021b), farmers' green production behavior categorize into

Table 2 Measurement of farmers' ecological cognition

Questions	Investigators scored according to the answers of farmers
1. Could you explain the meaning of "ecology"?	Understood = 1; Not understood = 0
2. Could you explain the meaning of "eco-livability[a]"?	Understood = 1; Not understood = 0
3. Could you explain the meaning of "global warming"?	Understood = 1; Not understood = 0
4. Could you explain the meaning of "Lucid waters and lush mountains are invaluable assets[b]"?	Understood = 1; Not understood = 0

[a]Eco-livability is a crucial part of China's rural revitalization strategy, which seeks a balanced development of rural society, economy, and environment. This strategy calls for the harmonious interaction between humans and nature, beginning with the construction of an ecological environment, and using a pleasant living environment to propel the growth of other aspects of rural life

[b]The report of the CPC's Twentieth National Congress pointed out that China should adhere to the concept that green mountains and clear waters are just as valuable as gold and silver mountains, adhere to the integrated protection and systematic governance of mountains, rivers, forests, fields, lakes, grass and sand, and strengthen the ecological environment protection in an all-round, all-regional and all-process manner. The "Two Mountains" concept has become a consensus and action, and provides a fundamental guideline for promoting the construction of ecological civilization in the new era and realizing the harmonious coexistence of man and nature

Table 3 Measurement of farmers' green production behavior

Questions	Investigators scored according to the answers of farmers
Do you use organic fertilizers in agricultural practices?	Yes = 1, No = 0
Have you taken any steps to reduce the application of chemical fertilizers?	Yes = 1, No = 0
How do you dispose of straws in general?	Straw incorporation, livestock feed or biogas production = 1; Fuel for cooking, dumping or burning = 0
How do you dispose of pesticide bottles or pesticide packaging waste?	Specialized recycling (placed in a designated place for special recycling) = 1; Discarded at random or disposed of by themselves (put in garbage bins, garbage dumps, etc.) = 0

a low green production behavior group and a high green production behavior group, with an average value of 1.03 as the threshold.

Based on the sample statistics, only 28% of the 399 samples in this paper exhibit consistency between farmers' ecological cognition and green production behavior. The consistency varies significantly concerning individual and family factors, as elaborated in Table 4. The deviation between the cognition and behavior of female farmers is higher than that of male farmers. As the educational level of farmers, health status, family political capital, family planting scales, and family total expenditure improve, the gap between their cognition and behavior gradually diminishes. Conversely, the inconsistency between cognition and behavior gradually widens with increasing age. Different numbers of raising and supporting have no noticeable effect on farmers' cognitive and behavioral deviation. Moreover, the influence of the agricultural labor ratio on farmers' cognitive and behavioral deviation does not exhibit any apparent regularity.

3.3.2 Independent variable

This paper posits that individual characteristics, family characteristics, and external factors exert an influence on the consistency between farmers' ecological cognition and green production behavior, drawing upon relevant studies (Fang et al., 2021; Gao et al., 2019; Qiao et al., 2022a; Shi et al., 2021) To account for these factors, the paper considers 18 independent variables across three domains. Table 5 provides detailed definitions and descriptive statistics for each variable."

3.4 Methods

3.4.1 Logistic model

The dependent variable in this study is "the consistency of farmers' ecological cognition and green production behavior," which is a typical binary decision variable, that is, when farmers' cognition and behavior are consistent, the value of the dependent variable is 1, otherwise, the value of the dependent variable is 0. Meanwhile, the dependent variable does not strictly obey the multivariate normal distribution, and the emphasis of the model is to find the influence

Table 4 Statistics on the consistency of cognition and behavior of sample farmers

Variable	Options	Consistency (%)	Inconsistency (%)	Variable	Options	Consistency (%)	Inconsistency (%)
Gender	Male	30.06	69.94	Political capital	Yes	30.31	69.69
	Female	20.55	79.45		No	24.83	75.17
Age/years old	< 35	49	51	Number of people raising and supporting/person	≤ 2	28.81	71.19
	35~44	23.08	76.92		3~4	27.48	72.52
	45~54	32.50	67.50		≥ 5	28.00	72.00
	55~64	23.53	76.47				
	≥ 65	19.44	80.56	Household expenditure/ten thousand yuan	< 3	25.32	74.68
					3~5	22.45	77.55
					5~8	32.14	67.86
Education level	Primary School and below	11.76	88.23		8~10	40.00	60.00
	Junior High School	29.95	70.05		≥ 10	41.02	58.97
	High School or Junior College	30.00	70.00				
	College and above	47.06	52.94	Planting scales/mu	≤ 5	18.47	81.53
					5~10	26.00	74.00
Health status	Unhealthy				10~20	31.43	68.57
	Healthy	9.68	90.32		20~30	44.12	55.88
					≥ 30	55.27	44.74
Agricultural labor ratio	≤ 0.5	25.67	74.32				
	0.5~1	36.59	63.41	Part-time employment	Yes	26.97	73.03
	1	27.82	72.18		No	29.41	70.58

Table 5 Variable definition and descriptive statistics

Variables	Definition	Mean	S. D	Min	Max	Expected
Dependent variable						
Consistency	Consistency of Ecological Cognition and Green Production Behavior: Consistency = 1, Inconsistency = 0	0.37	0.48	0	1	
Independent variables						
Individual characteristics						
Gender	Male = 1; Female = 0	0.82	0.38	0	1	+
Age	Actual age (years)	48.31	11.27	23	79	?
Education level	Actual years of education/years	9.21	3.08	0	18	+
Health status	Ranging from unhealthy (1) to healthy (3)	2.92	0.27	2	3	+
Part-time employment	Yes = 1, No = 0	0.45	0.50	0	1	–
Risk preference	Risk preference (ranging from very no preference (1) to very high preference (5))	2.37	1.53	1	5	+
Information acquisition	Whether to use the Internet to search for information? Yes = 1, No = 0	0.60	0.49	0	1	+
Policy cognition	Cognition of ecological protection policies? (ranging from very unfamiliar (1) to very unfamiliar (5))	2.40	1.19	1	5	+
Family characteristics						
Political capital	Whether the household members are civil servants or village cadre? Yes = 1, No = 0	0.36	0.49	0	1	+
Household expenditure	Household Actual expenditure in 2020/ ten thousand yuan	5.12	7.01	0.05	80	+
Number of people raising and supporting	Number of people raising and supporting/person	2.14	1.53	0	7	–
Agricultural labor ratio	Size of Agricultural labor force in household/number of the labor force	0.86	0.23	0.14	1	+
Planting scales	Actual planting scales/mu	15.01	27.37	0.50	260	?
External factors						
Land fragmentation	Number of plots/planting scale	0.87	0.73	0.01	5	–
Disaster impact	Degree of disaster impact: No effect = 1, Not serious = 2, Serious = 3	2.73	0.64	1	3	–
Peer influences	Are you easily influenced by the farmers around you? Yes = 1, No = 0	0.67	0.47	0	1	–
Social networks	Number of frequent visitors/person	43.14	44.19	1	250	+
Interpersonal trust	The level of trust in the people around you? (ranging from very distrustful (1) to very trustful (5))	3.84	1.30	1	5	?

factors of the dependent variable. The Logistic model can effectively limit the variable's value within the range of [0, 1], and is a classical model for analyzing influencing factors. Therefore, the Logistic model is selected for the study. The specific model is:

$$\mathrm{Ln}\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon \tag{1}$$

In Eq. 1, P represents the probability of consistency of farmers' ecological cognition and green production behavior, x_i is the influencing factor that affects the consistency of the farmers' ecological cognition and their green production behavior, $i = 1, 2, \ldots, n$. β_0 is a constant term, $\beta_1, \beta_2, \beta_3, \ldots, \beta_n$ are the parameters to be estimated, ε is the random error.

3.4.2 ISM

This study employs the ISM to scrutinize the hierarchical structure and interactions among the factors and reveal their paths of action. ISM was originally proposed to analyze the structural problems of complex economic and social systems (Warfield, 1973). It is commonly used to explore the structure and hierarchy of a system, to identify the key factors of the system, and to study the logical hierarchy among the factors (Hao et al., 2023; Qiao et al., 2022b). The basic principle is to use relevant logical structure diagrams and MATLAB software to deal with the relationship of the influencing factors, determine the correlation and hierarchy between them, and analyze the intrinsic connection between them. Compared with other methods in hierarchical analysis, ISM is more suitable for the systematic analysis of many variables, complex relationships, and unclear structures (Zhang et al., 2020). In recent years, it has been widely used in studies on factors influencing food security (Lin et al., 2019), and factors influencing willing-behavior inconsistency (Qiao et al., 2022a, 2022b). In this paper, the factors influencing farmers' consistency of cognition-behavior are both independent of each other but interrelated, which forms a multilevel, ladder-form hierarchical structure.

Therefore, this paper introduces the ISM method to deeply scrutinize the hierarchical structure and interactions among the factors and unveil their paths of action. The steps of the ISM method are shown: (1) determine the logical relationship between the factors; (2) determine the adjacency matrix R_{ij} between the factors; (3) determine the reachability matrix M_{ij} between factors; (4) determine the hierarchy of the factors and obtain the ranked reachability matrix. (5) determine the inter-factor hierarchy.

In this model, S_0 indicates the "consistency of farmers' ecological cognition and green production behavior." S_i ($i = 1, 2, \ldots, k$) indicates the significant factor (influencing the "consistency") of i. Logical relationships are obtained based on the judgment of the logical relationships among the significant influencing factors. Then, the adjacency matrix R_{ij} is determined based on the logical relationships. Where the elements in the adjacency matrix are S_{ij}.

$$S_{ij} = \begin{cases} 1, & (S_i \text{ is related to } S_j) \\ 0, & (S_i \text{ is not related to } S_j) \end{cases} \quad I, j = 1, 2, \ldots, k \tag{2}$$

Then, the reachable matrix M_{ij} can be calculated using formula 3 below.

$$M_{ij} = (R + I)^{\lambda+1} = (R + I)^{\lambda} \neq (R + I)^{\lambda-1} \neq \cdots \neq (R + I)^2 \neq (R + I) \tag{3}$$

In the formula, $2 \leq \lambda \leq k$, I is a unit matrix, and the Boolean operation rule is used in the power operation of the matrix. The determination formula of each factor from the highest level to the lowest level is as follows:

$$L = \{S_i | P(S_i)\Omega Q(S_i) = P(S_i); \quad i = 0, 1, \ldots, k\} \tag{4}$$

In Eq. 4, $P(S_i)$ represents the set of column elements corresponding to the matrix elements containing “1” in the row corresponding to element S_i of the reachable matrix M_{ij}, $Q(S_i)$ represents the set of elements in the rows corresponding to the matrix elements containing “1” in the column corresponding to the element Si in the reachable matrix M_{ij}. Formula 4 is used to first determine the first level (L_1) factors, and then gradually determine the other levels of factors.

4 Results

4.1 Logistic regression results

The Stata15.1 software is utilized in this paper to estimate the Logistic model. Variables are tested before performing the regression analysis to avoid multicollinearity issues. The findings indicate that none of the selected variables has collinearity problems, as their variance inflation factors (VIF) were less than 5, with a maximum value of 2 and a mean value of 1.30. The outcome of the model estimation is presented in Table 6, where column 1 displays the probit model results, and column 2 presents the binary Logistic model results. Two models have consistent coefficients and significance levels, confirming the robustness of the findings. Moreover, the model successfully passed the 1% significance test in column 2, demonstrating an overall good fit for subsequent analysis. The regression results are displayed in Table 6.

(1) Individual characteristics

The education level of farmers has a positive impact on the consistency between ecological cognition and green production practices. This correlation is significant at the 5% level, indicating that farmers with higher levels of education are more likely to have a consistent behavior toward green production in line with their ecological cognition. This can be attributed to the fact that Compared with farmers with low education levels, those with high education levels have a better understanding of ecological concepts and the meaning of green production. Therefore, they are more willing to implement green production practices in agricultural production. Health status also positively affects farmers’ cognition and behavior at the 10% level, suggesting that healthier farmers are more likely to practice green production in line with their ecological cognition. This is likely because healthier farmers find it easier to learn and adopt new green production practices. Thus, farmers are more likely to transform their attitudes into green production practices as their cognition probability increases. Risk preference shows a significant positive impact on consistency at the 10% level, which suggests that the behavior of risk-averse farmers is more consistent with their cognition. This is because green production involves uncertain risk, and risk-preferring farmers are better able to tolerate hazards and more open-minded to innovation. Therefore, they are more inclined to implement green production practices and facilitate the conversion of farmers’ cognition into practical applications. Information acquisition also positively influences on consistency between farmers’ cognition and behavior at the 5% level, which implies that farmers more skilled in gaining knowledge through the Internet are likelier to have consistency of cognition and behavior. This result is

Table 6 Estimation results of the Logistic model

Variables	Model (1)	Model (2)
Individual characteristics		
Gender	0.243 (0.046)	0.443 (0.563)
Age	0.000 (0.002)	− 0.000 (0.015)
Education level	0.068** (0.006)	0.110** (0.057)
Health status	− 0.795** (0.065)	1.226* (2.362)
Part-time employment	0.244 (0.042)	− 0.399 (0.184)
Risk preference	0.089* (0.013)	0.151* (0.094)
Information acquisition	0.481** (0.048)	0.822** (0.754)
Policy cognition	0.219*** (0.016)	0.368*** (0.156)
Family characteristics		
Political capital	0.544** (0.042)	0.905*** (0.123)
Household expenditure	0.034** (0.004)	0.055** (0.029)
Number of people raising and supporting	− 0.049 (0.013)	− 0.074 (0.082)
Agricultural labor ratio	0.390 (0.087)	0.732 (1.218)
Actual planting scales	0.007** (0.001)	− 0.013** (0.006)
External factors		
Land fragmentation	0.310 (0.030)	0.055 (0.214)
Disaster impact	− 0.170 (0.017)	− 0.279 (0.152)
Peer influences	− 0.428*** (0.045)	− 0.716*** (0.131)
Social networks	0.003* (0.002)	0.005* (0.003)
Interpersonal trust	− 0.074 (0.059)	− 0.134 (0.088)
Cons	− 3.614*** (1.096)	− 5.865*** (0.006)
N	399	399
− 2 Log likelihood	390.102	391.985
Prob > chi2	0.000	0.000

***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively

close to the view of Zheng et al. (2022). This could be attributed to the fact that farmers who are more adept at acquiring online information have easier access to important information, such as environmental policy information, environmental status information, and the significance of green production, which can improve farmers' awareness of environmental protection and promote them to adopt green production technologies in agricultural production. Policy cognition has a positive impact on the consistency of cognition-behavior. This effect is significant at the 1% level, indicating that farmers who have a better understanding of policies are more likely to behave consistently with their knowledge of ecological protection and green production. The reason for this may be that greater knowledge of policies leads to a deeper understanding of environmental protection and green production, which increases the likelihood of implementing eco-friendly practices. Gender, age, and part-time employment have no significant impact on the consistency of farmers' ecological cognition and green production behavior. This may be because most farmers in the study were male, middle-aged, or older, and they did not have part-time employment. These independent variables have small variability. Thus, they do not significantly affect the outcome.

(2) Household characteristics

The consistency of farmers' ecological cognition and green production behavior is positively impacted by the level of political capital in their households. This effect is significant at the 1% level, suggesting that higher political capital leads to better consistency between cognition and behavior. The finding is similar to the results of Cishahayo et al. (2023). This can be attributed to farmers who hold civil servant or village cadre positions having a better understanding of national policies and guidelines, resulting in a deeper awareness of the importance of green production. Consequently, their cognition is translated into concrete green production behavior. Furthermore, the household expenditure level also positively impacts the consistency of farmers' cognition and behavior. This effect is significant at the 1% level, meaning that higher household expenditure increases the likelihood of consistent practice of green production. This is likely because green production requires more investment than regular agricultural production. Therefore, the higher the total household expenditure, the more likely farmers are to invest in green products, enabling them to implement green production practices and transform their cognition into action. Additionally, the regression coefficient of the planting scales is significant and negative at a 5% level. This suggests that as the family planting scales increase, there is a reduced likelihood of consistency between cognition and behavior. This could be explained by the fact that farmers with larger planting scales are required to incur more opportunity costs in implementing green production and are more prudent in behavioral decision-making, which restricts the transformation of cognition into actual behavior. The coefficients estimated for the number of people raising and supporting and the agricultural labor ratio are insignificant, indicating that they do not substantially impact the correlation between farmers' ecological cognition and green production behavior.

(3) External factors

Social networks significantly and positively impact farmers' consistency toward ecological cognition and green production behavior. This effect is statistically significant at the 5% level, indicating that social networks can enhance the consistency between farmers' knowledge and actions. One plausible explanation for this result is that farmers with more robust social networks can access more contacts to obtain information regarding sustainable practices, leading to increased comprehension of eco-friendly farming techniques. As a result, farmers can improve their ecological cognition and implement better environmental production behavior. The regression coefficient of peer influences is negative and significant at the 1% level, suggesting that farmers more influenced by their peers were less likely to act consistently with their ecological cognition compared to those who were less influenced by their peers. Farmers who rely heavily on their peers tend to take a cautious approach when making decisions about their behavior. When faced with a new green production technology, farmers who rely on their peers will observe whether their peers in the same village are using the technology, then they will adopt it only when they see that most people are using it, which could prevent them from translating their ecological cognition into concrete actions toward sustainable farming practices. However, factors such as land fragmentation, disaster impact, and interpersonal trust did not significantly affect farmers' consistency of cognition- behavior.

4.2 Hierarchical structural decomposition of the factors influencing the "consistency"

Based on the Logistic regression model results, we identified the significant factors that influence the consistency of farmers' ecological cognition and green production behavior. Through a hierarchical analysis, we have examined the interrelationships among these factors, which include S_0 for "consistency," S_1 for education level, S_2 for health status, S_3 for political capital, S_4 for household expenditure, S_5 for planting scales, S_6 for risk preference, S_7 for peer influences, S_8 for policy cognition, S_9 for social networks, and S_{10} for information acquisition. The logical relationships between these factors were determined based on theoretical analysis and expert opinions. Figure 2 shows the direct or indirect effects of the factors on the rows denoted by V, while the factors on the columns are denoted by A. Mutual effects between the factors on the rows and columns are denoted by O.

To obtain the adjacency matrix R_{ij} among factors using Fig. 2 and formula 2, the reachable matrix M_{ij} can be calculated by using the software matlab2021a. The influence factors in M_{ij} are then reordered based on their hierarchy to create a sorted reachability matrix M'_{ij}.

$$Rij = \begin{matrix} S0 \\ S1 \\ S2 \\ S3 \\ S4 \\ S5 \\ S6 \\ S7 \\ S8 \\ S9 \\ S10 \end{matrix} \begin{bmatrix} 0&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&1&1&1&1 \\ 1&0&0&0&0&1&1&0&0&1&0 \\ 1&0&0&0&0&0&0&0&1&1&1 \\ 1&0&0&0&0&1&1&0&0&1&0 \\ 1&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&0&0&0&0 \\ 1&0&0&0&0&0&0&1&0&0&0 \end{bmatrix} \tag{5}$$

Fig. 2 Logical relationship of influencing factors

A	A	A	A	A	A	A	A	A	A	S_0
V	V	V	O	O	O	O	O	O	S_1	
O	V	O	O	V	V	O	O	S_2		
V	V	V	O	O	O	O	S_3			
V	V	O	O	V	V	S_4				
O	O	O	O	V	S_5					
O	O	O	O	S_6						
A	A	A	S_7							
O	O	S_8								
O	S_9									
S_{10}										

$$Mij = \begin{matrix} S0 \\ S1 \\ S2 \\ S3 \\ S4 \\ S5 \\ S6 \\ S7 \\ S8 \\ S9 \\ S10 \end{matrix} \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \end{bmatrix} \tag{6}$$

$$M'_{ij} = \begin{matrix} S_0 \\ S_6 \\ S_7 \\ S_5 \\ S_8 \\ S_9 \\ S_{10} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \end{matrix} \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \tag{7}$$

Finally, by using the method to determine the most important factors, we obtained the following sets: $L_1=\{S_0\}$, $L_2=\{S_1, S_7\}$, $L_3=\{S_5, S_8, S_9, S_{10}\}$, $L_4=\{S_1, S_2, S_3, S_4\}$. By recalculating the reachability matrix at each level mentioned above, we were able to obtain a hierarchical structure for the factors, which is depicted in Fig. 3.

Various factors influence the consistency between farmers' ecological cognition and green production behavior (Fig. 3). Peer influences and risk preference are direct and surface factors. Intermediate-level indirect factors include planting scales, policy cognition, information acquisition, and social networks. Deep-rooted factors that affect consistency include farmers' education level, health status, political capital, and household expenditure. These factors can be independent or interrelated, with deep-rooted factors influencing intermediate-level indirect factors. While they also influence surface-level direct factors. The consistency of farmers' cognition and behavior is influenced by these three paths.

Path 1 Farmer's education level, political capital → policy cognition, information acquisition, and social networks → peer influences → the consistency of farmers' ecological cognition and green production behavior. To explain this path, firstly, farmers' education level and household political capital influence their ability to understand policies, search for information online, and the capacity of their social networks. Secondly, a farmer's policy

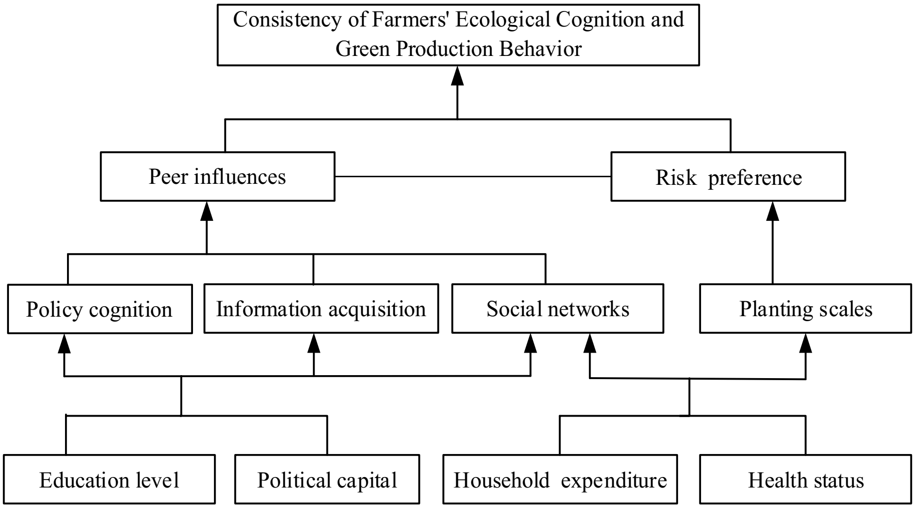

Fig. 3 Interpretative structural model of the influencing factors

cognition, information acquisition, and social networks can impact the strength of peer influences. Finally, peer influences impact the consistency of farmers' cognition-behavior.

Path 2 Household political capital, health status → social networks → peer influences → the consistency between cognition and behavior. Three factors are interconnective in this context. The first factor is the total expenditure of households and the health status of farmers, which can impact the strength of their social networks. Secondly, farmers' social networks can influence the extent of their peer influences. Finally, the level of peer influences can affect the "consistency."

Path 3 Household political capital, health status → planting scales → risk preferences → the consistency of cognition-behavior. There are three interconnected factors in this context. The first factor is farmers' household expenditure and health status, which can influence the size of the crops planted by the farmers. Secondly, the scales of the crops planted by the farmers can affect their degree of risk preferences. Finally, farmers' degree of risk preference can impact the "consistency."

5 Conclusions and discussion

It is significant for farmers to carry out green production to promote green and high-quality agricultural development, to produce green and healthy agricultural products, and to realize rural ecological revitalization. Based on a sample of 399 farmers in Hainan Province, this paper uses the Logistic-ISM approach to analyze the underlying mechanisms that influence the consistency between farmers' ecological cognition and green production behavior, as well as the significant factors that affect the transformation of ecological cognition into actual behavior, which can help to promote farmers' green production behavior and realize the green development of global agriculture. Firstly, this paper uses the Logistic model to empirically analyze the factors influencing the consistency of farmers' cognition and behavior, and subsequently uses the ISM method to explore the logical hierarchy of the influencing factors. The main conclusions are as follows:

Firstly, the study's results reveal that 72% of farmers exhibit inconsistencies between their green production behavior and ecological cognitions. Secondly, education level, health status, household political capital, household expenditure, risk preference, policy cognition, social networks, and information acquisition significantly and positively influence the consistency of farmers' ecological cognition and green production behavior. Additionally, planting scales and peer influences have a negative influence on consistency. Finally, among the significant influencing factors, peer influences, and risk preference are surface-level direct factors. Planting size, policy cognition, information acquisition, and social networks are intermediate-level indirect factors. Deep-rooted factors are farmers' education level, health status, household political capital, and household expenditure.

Compared with recent studies, the results of this study are consistent with some existing studies. Such as Wang et al. (2023) and Foguesatto et al. (2020), who also verified certain results of this paper and asserted that farmers' adoption of green production technologies is influenced by individual characteristics like education level and health status, household characteristics like planting scale and annual household income, and external factors like social networks and peer influences. However, in contrast to previous studies on the factors influencing the consistency of farmers' green production behavior and ecological cognition, this paper focuses not simply on the "consistency or not" (Deng et al., 2021), but on the consistency between behavior with cognition on high ecological cognition level and the hierarchical structure of influencing factors. Moreover, the paper selects four types of green production status to represent farmers' green production behavior, including organic fertilizer application, chemical fertilizers reduction, treating straw, and treating pesticide waste, providing a more comprehensive characterization of green production behavior. In contrast, previous studies have mostly focused on one type of green production behavior (Ren, 2023). Secondly, unlike other studies that use only the Logit model or Probit model, this study also uses the ISM method to further focus on the logical hierarchy of the influencing factors, which is rarely seen in the existing studies on farmers' cognition-behavior' consistency. Overall, the main contribution of this paper is that the findings are generalizable and accurate, and it also provides a more in-depth and detailed understanding of the factors that influence the consistency between farmers' behavior and cognition.

In addition, there are also some limitations in the study. Firstly, the heterogeneity of agricultural green production behavior itself may lead to deviations in farmers' ecological cognition and green production behavior, and this study focused only on individual and household characteristics and external factors without considering the attributes of green behavior in agriculture. Therefore, future research could explore the heterogeneity of different green production behaviors and how this affects the consistency of farmers' cognition and behavior. Secondly, the study only explored farmers' cognition and behavior from the dimension of ecological cognition. Thus, future studies can simultaneously select multiple green cognitive dimensions to explore deviations in farmers' cognition and behavior simultaneously. Finally, concerning research methodologies, the ISM approach, which establishes the logical connections between diverse factors based on the insights of experts and scholars, subsequently determining the adjacency matrix R_{ij}, may entail a certain degree of subjectivity. Future research could contemplate the adoption of more objective methodologies to ascertain the logical relationships among these factors.

Although this study has some limitations, the findings still have practical implications for the interested stakeholders to formulate policies. Firstly, Effective policies should balance the improvement of ecological cognition and a high proportion of implementation behavior. The interested stakeholders should recognize this fact, improve the publicity and training mechanisms for farmers, and innovate the help system to solve farmers' agricultural production difficulties. To enhance the transformation of farmers' ecological cognition into actual green production behavior, the interested stakeholders should avoid the inhibiting effect of a single factor on the consistency of cognition and behavior of farmers. Additionally, factors such as farmers' education level, health status, household political capital, and household expenditure are deep-rooted, and the interested stakeholders should pay more attention to their influence when formulating policies. For example, firstly, the interested stakeholders should strengthen investment in rural education, improve the rural education system, conduct training courses on ecological and environmental protection and green agricultural production for farmers, provide a platform for farmers to obtain and understand relevant information, and promote the simultaneous improvement of their ecological cognition and green production behavior. Secondly, the interested stakeholders should utilize the guidance and dissemination role of local household civil servants and village cadres, organize training and propaganda for local civil servants in the countryside, and promote the transformation of farmers' cognition into behavior. Finally, the interested stakeholders should innovate system and model innovation, optimize agricultural subsidies and input methods, improve policy tools, clarify the focus of financial support, increase subsidies for green production methods, and give extra care to families with poor economic status to facilitate the transformation of farmers' cognition into actual green products and ensure the long-term effectiveness of farmers' green production behavior.

Acknowledgements This study was supported in part by the National Natural Science Foundation of China (72003054, 72103052), Natural Science Foundation of Hainan (722RC630; 720QN243; 720RC576), and the project of postgraduate innovation of Hainan (Qhys2021-84).

Author contribution All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by WE-L, DQ, TX. The first draft of the manuscript was written by WQ-L and TX. QC-H,YF-J and DH-C Chencommented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability Not applicable.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval This is an observational study, and we confirmed that no ethical approval is required.

Consent to participate Not applicable.

Consent for publication Not applicable.

References

Baah, C., Opoku-Agyeman, D., Acquah, I. S. K., Agyabeng-Mensah, Y., Afum, E., Faibil, D., & Abdoulaye, F. A. M. (2021). Examining the correlations between stakeholder pressures, green production practices, firm reputation, environmental and financial performance: Evidence from manufacturing SMEs. *Sustainable Production and Consumption, 27*, 100–114. https://doi.org/10.1016/j.spc.2020.10.015

Cai, J. Y., Xiong, J. J., Hong, Y., & Hu, R. F. (2021). Pesticide overuse in apple production and its socioeconomic determinants: Evidence from Shaanxi and Shandong provinces, China. *Journal of Cleaner Production, 315*, 128179. https://doi.org/10.1016/j.jclepro.2021.128179

Cao, A., Guo, L., & Li, H. (2022). How does land renting-in affect chemical fertilizer use? The mediating role of land scale and land fragmentation. *Journal of Cleaner Production, 379*, 134791. https://doi.org/10.1016/j.jclepro.2022.134791

Cao, H., Zhu, X., Heijman, W., & Zhao, K. (2020). The impact of land transfer and farmers' knowledge of farmland protection policy on pro-environmental agricultural practices: The case of straw return to fields in Ningxia, China. *Journal of Cleaner Production, 277*, 123701. https://doi.org/10.1016/j.jclepro.2020.123701

Chen, S. L., Su, Y. S., Diep, G. L., Sivanandan, P., Sadiq, M., & Phan, T. T. H. (2023). The impact of environmental knowledge and green supply chain practices in improving sustainable energy production: The moderating role of green behavior and green leadership. *Environmental Science and Pollution Research, 30*, 57017–57031. https://doi.org/10.1007/s11356-023-26340-7

Chen, Z., Li, X., & Xia, X. (2022). Socioeconomic status, ambidextrous learning, and farmers' adoption of biological control technology: Evidence from 650 kiwifruit growers in China. *Pest Management Science, 78*(2), 475–487. https://doi.org/10.1002/ps.6642

Cishahayo, L., Zhu, Y., Zhang, C., & Wang, F. (2023). Impacts of social capital on climate change adaptations of banana farmers in Southern China. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-03729-5

Conley, T. G., & Udry, C. R. (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review, 100*(1), 35–69. https://doi.org/10.1257/aer.100.1.35

Deng, Z., Dai, L., Deng, L., & Peng, P. (2021). Analysis of farmers' perceptions and behavioral response to rural living environment renovation in a major rice-producing area: a case of Dongting Lake Wetland, China. *Ciência Rural*. https://doi.org/10.1590/0103-8478cr20200847

Dougherty, J. P., Flatnes, J. E., Gallenstein, R. A., Miranda, M. J., & Sam, A. G. (2020). Climate change and index insurance demand: Evidence from a framed field experiment in Tanzania. *Journal of Economic Behavior & Organization, 175*, 155–184. https://doi.org/10.1016/j.jebo.2020.04.016

Fang, X., Wang, L., Sun, C., Zheng, X., & Wei, J. (2021). Gap between words and actions: Empirical study on consistency of residents supporting renewable energy development in China. *Energy Policy, 148*, 111945. https://doi.org/10.1016/j.enpol.2020.111945

Finger, R., & Möhring, N. (2022). The adoption of pesticide-free wheat production and farmers' perceptions of its environmental and health effects. *Ecological Economics, 198*, 107463. https://doi.org/10.1016/j.ecolecon.2022.107463

Foguesatto, C. R., Borges, J. A. R., & Machado, J. A. D. (2020). A review and some reflections on farmers' adoption of sustainable agricultural practices worldwide. *Science of the Total Environment, 729*, 138831. https://doi.org/10.1016/j.scitotenv.2020.138831

Gao, Y., Liu, B., Yu, L., Yang, H., & Yin, S. (2019). Social capital, land tenure and the adoption of green control techniques by family farms: Evidence from Shandong and Henan Provinces of China. *Land Use Policy, 89*, 104250. https://doi.org/10.1016/j.landusepol.2019.104250

Gebre, G. G., Isoda, H., Rahut, D. B., Amekawa, Y., & Nomura, H. (2019). Gender differences in the adoption of agricultural technology: The case of improved maize varieties in southern Ethiopia. *Women's Studies International Forum, 76*, 102264. https://doi.org/10.1016/j.wsif.2019.102264

Hao, Q., Xu, S., Liao, Y., Qiao, D., Shi, H., & Xu, T. (2023). Determinants of residents' willingness to pay for water quality improvements in Haikou, China: Application of CVM and ISM approaches. *Water, 15*(7), 1305. https://doi.org/10.3390/w15071305

He, K., Ye, L., Li, F., Chang, H., Wang, A., Luo, S., & Zhang, J. (2022). Using cognition and risk to explain the intention-behavior gap on bioenergy production: Based on machine learning logistic regression method. *Energy Economics, 108*, 105885. https://doi.org/10.1016/j.eneco.2022.105885

Holden, S. T., & Quiggin, J. (2017). Climate risk and state-contingent technology adoption: Shocks, drought tolerance and preferences. *European Review of Agricultural Economics, 44*(2), 285–308. https://doi.org/10.1093/erae/jbw016

Huang, W., Qi, Z., Wu, L., & Hu, J. (2016). Influence of environmental awareness on environmental-friendly behavior of farmers: Exploring the moderating role of community environment. *Journal of China Agriculture University China, 21*(11), 155–164.

Jianjun, J., Yiwei, G., Xiaomin, W., & Nam, P. K. (2015). Farmers' risk preferences and their climate change adaptation strategies in the Yongqiao District, China. *Land Use Policy, 47*, 365–372. https://doi.org/10.1016/j.landusepol.2015.04.028

Kuang, F., Chen, M., Li, Z., Peng, X., Liu, J., & Liu, Y. (2018). Analysis on differences between farmers' ecological cognition and protective behavior based on using pesticide and chemical fertilizer. *Research of Soil and Water Conservation China, 25*(01), 321–326. https://doi.org/10.13869/j.cnki.rswc.2018.01.049

Li, Z., Jin, M., & Cheng, J. (2021c). Economic growth of green agriculture and its influencing factors in china: Based on emergy theory and spatial econometric model. *Environment, Development and Sustainability, 23*, 15494–15512. https://doi.org/10.1007/s10668-021-01307-1/metrics

Li, Y., Qing, C., Guo, S., Deng, X., Song, J., & Xu, D. (2023). Will farmers follow their peers in adopting straw returning? Evidence from rural Sichuan Province, China. *Environmental Science and Pollution Research, 30*(8), 21169–21185. https://doi.org/10.1007/s11356-022-23648-8/metrics

Li, B., Ding, J., Wang, J., Zhang, B., & Zhang, L. (2021a). Key factors affecting the adoption willingness, behavior, and willingness-behavior consistency of farmers regarding photovoltaic agriculture in China. *Energy Policy, 149*, 112101. https://doi.org/10.1016/j.enpol.2020.112101

Li, B., & Shen, Y. (2021). Effects of land transfer quality on the application of organic fertilizer by large-scale farmers in China. *Land Use Policy, 100*, 105124. https://doi.org/10.1016/j.landusepol.2020.105124

Li, C., Guo, J., Xu, X., Sun, M., & Zhang, L. (2021b). Determinants of smallholder farmers' choice on mulch film thickness in rural China. *Environmental Science and Pollution Research, 28*, 45545–45556. https://doi.org/10.1007/s11356-021-13866-x

Lin, X., Cui, S., Han, Y., Geng, Z., & Zhong, Y. (2019). An improved ISM method based on GRA for hierarchical analyzing the influencing factors of food safety. *Food Control, 99*, 48–56. https://doi.org/10.1016/j.foodcont.2018.12.020

Liu, E. K., He, W. Q., & Yan, C. R. (2014). 'White revolution' to 'white pollution'—Agricultural plastic film mulch in China. *Environmental Research Letters, 9*(9), 091001. https://doi.org/10.1088/1748-9326/9/9/091001

Liu, Y., Cheng, X., & Li, W. (2021). Agricultural chemicals and sustainable development: The agricultural environment Kuznets curve based on spatial panel model. *Environmental Science and Pollution Research, 28*(37), 51453–51470. https://doi.org/10.1007/s11356-021-14294-7

Liu, H., & Zhou, Y. (2018). Farmers' cognition and behavioral response towards cultivated land quality protection in Northeast China. *Sustainability, 10*(6), 1905. https://doi.org/10.3390/su10061905

Liu, W., Liu, L., Guan, C., Zhang, F., Li, M., Lv, H., Yao, P., & Ingenhoff, J. (2018). A novel agricultural photovoltaic system based on solar spectrum separation. *Solar Energy, 162*, 84–94. https://doi.org/10.1016/j.solener.2017.12.053

Luo, J., Huang, M., & Bai, Y. (2023). Promoting green development of agriculture based on low-carbon policies and green preferences: An evolutionary game analysis. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-023-02970-2

Mao, H., Zhou, L., Ying, R., & Pan, D. (2021). Time Preferences and green agricultural technology adoption: Field evidence from rice farmers in China. *Land Use Policy, 109*, 105627. https://doi.org/10.1016/j.landusepol.2021.105627

Mohring, N., Wuepper, D., Musa, T., & Finger, R. (2020). Why farmers deviate from recommended pesticide timing: The role of uncertainty and information. *Pest Management Science, 76*(8), 2787–2798. https://doi.org/10.1002/ps.5826

Noll, D., Dawes, C., & Rai, V. (2014). Solar community organizations and active peer effects in the adoption of residential PV. *Energy Policy, 67*, 330–343. https://doi.org/10.1016/j.enpol.2013.12.050

Qiao, D., Li, W., Zhang, D., Yan, Y., & Xu, T. (2022a). How do you want to restore?–Assessing the public preferences and social benefits of ecological restoration for natural rubber plantation in China. *Frontiers in Environmental Science*. https://doi.org/10.3389/fenvs.2022.823778

Qiao, D., Xu, S., Xu, T., Hao, Q., & Zhong, Z. (2022b). Gap between willingness and behavior: Understanding the consistency of farmers' green production in Hainan, China. *International Journal of Environmental Research and Public Health, 19*(18), 11651. https://doi.org/10.3390/ijerph191811351

Qin, S.-l, & Lü, X.-Y. (2020). Do large-scale farmers use more pesticides? Empirical evidence from rice farmers in five Chinese provinces. *Journal of Integrative Agriculture, 19*(2), 590–599. https://doi.org/10.1016/S2095-3119(19)62864-9

Qing, C., Guo, S., Deng, X., & Xu, D. (2021). Farmers' awareness of environmental protection and rural residential environment improvement: A case study of Sichuan province, China. *Environment, Development and Sustainability, 24*, 11301–11319. https://doi.org/10.1007/s10668-021-01909-9

Qiu, X., Jin, J., He, R., & Mao, J. (2022). The deviation between the willingness and behavior of farmers to adopt electricity-saving tricycles and its influencing factors in Dazu District of China. *Energy Policy, 167*, 113069. https://doi.org/10.1016/j.enpol.2022.113069

Ren, J., Lei, H., & Ren, H. (2022). Livelihood capital, ecological cognition, and farmers' green production behavior. *Sustainability, 14*(24), 16671. https://doi.org/10.3390/su142416671

Ren, Z. (2023). Effects of risk perception and agricultural socialized services on farmers' organic fertilizer application behavior: Evidence from Shandong Province, China. *Frontiers in Public Health, 11*, 1056678. https://doi.org/10.3389/fpubh.2023.1056678

Shang, G. Y., & Yang, X. (2021). Impacts of policy cognition on low-carbon agricultural technology adoption of farmers. *Ying Yong Sheng Tai Xue Bao= the Journal of Applied Ecology, 32*(4), 1373–1382. https://doi.org/10.13287/j.1001-9332.202104.024

Shi, Y., Li, C., & Zhao, M. (2021). Herders' aversion to wildlife population increases in grassland ecosystem conservation: Evidence from a choice experiment study. *Global Ecology and Conservation, 30*, e01777. https://doi.org/10.1016/j.gecco.2021.e01777

Simtowe, F., Mduma, J., Phiri, A., Thomas, A., & Zeller, M. (2006). Can risk-aversion towards fertilizer explain part of the non-adoption puzzle for hybrid maize? Empirical evidence from malawi. *Journal of Applied Sciences, 6*(7), 1490–1498.

Vahmani, P., Sun, F., Hall, A., & Ban-Weiss, G. (2016). Investigating the climate impacts of urbanization and the potential for cool roofs to counter future climate change in Southern California. *Environmental Research Letters, 11*(12), 124027. https://doi.org/10.1088/1748-9326/11/12/124027

Wang, C., & Gu, H. (2012). Farmers' perception of environment, behavior decision and the check of consistency between them-a empirical analysis based On the survey of farmers in jiangsu province. *Resources and Environment in the Yangtze Basin, China, 21*(10), 1204–1208.

Wang, F., Cang, Y., Chen, S., & Ke, Y. (2023). Aging, land fragmentation, and banana farmers' adoption of biopesticides in China. *Environmental Science and Pollution Research, 30*(35), 84742–84757. https://doi.org/10.1007/s11356-023-28358-3

Wang, H., Wang, X., Sarkar, A., & Zhang, F. (2021a). How capital endowment and ecological cognition affect environment-friendly technology adoption: A case of apple farmers of Shandong Province, China. *International Journal of Environmental Research and Public Health, 18*(14), 7571. https://doi.org/10.3390/ijerph18147571

Wang, J., Chu, M., & Ma, Y. (2018). Measuring rice farmer's pesticide overuse practice and the determinants: A statistical analysis based on data collected in Jiangsu and Anhui Provinces of China. *Sustainability, 10*(03), 0677. https://doi.org/10.3390/su10030677

Wang, X., Zhang, J., He, K., & Li, W. (2021b). Place attachment, environmental cognition and organic fertilizer adoption of farmers: Evidence from rural China. *Environmental Science and Pollution Research, 28*, 41255–41267. https://doi.org/10.1007/s11356-021-13509-1

Warfield, J. N. (1973). Binary matrices in system modeling. *IEEE Transactions on Systems, Man, and Cybernetics, 5*, 441–449. https://doi.org/10.1109/TSMC.1973.4309270

Wilson, C., & Dowlatabadi, H. (2007). Models of decision making and residential energy use. *Annual Review of Environment and Resources, 32*, 169–203. https://doi.org/10.1146/annurev.energy.32.053006.141137

Xie, H., & Huang, Y. (2021). Influencing factors of farmers' adoption of pro-environmental agricultural technologies in China: Meta-analysis. *Land Use Policy, 109*, 105622. https://doi.org/10.1016/j.landusepol.2021.105622Returntoref2021inarticle

Yazdanpanah, M., Feyzabad, F. R., Forouzani, M., Mohammadzadeh, S., & Burton, R. J. F. (2015). Predicting farmers' water conservation goals and behavior in Iran: A test of social cognitive theory. *Land Use Policy, 47*, 401–407. https://doi.org/10.1016/j.landusepol.2015.04.022

Zhang, J., Chen, M., Huang, C., & Lai, Z. (2022). Labor endowment, cultivated land fragmentation, and ecological farming adoption strategies among farmers in Jiangxi Province, China. *Land, 11*(5), 679. https://doi.org/10.3390/land11050679

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

Zheng, W., Luo, B., & Hu, X. (2020). The determinants of farmers' fertilizers and pesticides use behavior in China: An explanation based on label effect. *Journal of Cleaner Production, 272*, 123054. https://doi.org/10.1016/j.jclepro.2020.123054

Zheng, Y., Zhu, T., & Wei, J. (2022). Does Internet use promote the adoption of agricultural technology? Evidence from 1 449 farm households in 14 Chinese provinces. *Journal of Integrative Agriculture, 21*(1), 282–292. https://doi.org/10.1016/S2095-3119(21)63750-4

Zhou, J., Yan, Z., & Li, K. (2016). Understanding farmer cooperatives' self-inspection behavior to guarantee agri-product safety in China. *Food Control, 59*, 320–327. https://doi.org/10.1016/j.foodcont.2015.05.035

Zhu, W., & Wang, R. (2021). Impact of farm size on intensity of pesticide use: Evidence from China. *Science of the Total Environmen, 753*, 141696. https://doi.org/10.1016/j.scitotenv.2020.141696

Authors and Affiliations

Weiqin Li[1] · Dan Qiao[1] · Qinchuan Hao[1] · Yifan Ji[1] · Donghui Chen[1] · Tao Xu[1]

✉ Tao Xu
xutao_2013@outlook.com

Weiqin Li
liweiqin0126@163.com

Dan Qiao
qiaodan1124@126.com

Qinchuan Hao
haoqinchuan@163.com

Yifan Ji
jiyifan0324@163.com

Donghui Chen
cdhui1998@163.com

[1] International Business School of Hainan University, No 58, Renmin Avenue, Haikou 570228, Hainan, People's Republic of China