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Influencing factors and mechanisms of farmers' participation in promoting the effect of rural environmental governance—a qualitative comparative analysis based on Chinese cases

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Introduction: Farmers' participation is the key to promoting the good governance of the rural environment, but the discussion on the effectiveness of farmers' participation in rural environmental governance is still weak.

Methods: A "dynamic-process-guarantee" analytical framework was constructed, and a crisp-set qualitative comparative analysis method was used to explore the linkage effect of various factors such as participation ability, interest correlation, participation channel, supervision & punishment, demand response, and information disclosure, and the path and mechanism of farmers' participation in improving the effect of rural environmental governance was analyzed.

Results: The findings indicate that farmers' participation in improving the effect of rural environmental governance is the result of multi-factor coupling, and a single factor does not constitute the necessary condition for farmers' participation in promoting good environmental governance. Participation channel is sufficient conditions for farmers to participate in improving the effect of rural environmental governance. There are five paths and three mechanisms for forming good rural environmental governance effects. Lack of participation ability is a necessary condition for the poor effect of rural environmental governance, and limited participation channels constitute a sufficient condition.

Discussion: From the perspective of configuration, the research systematically explains the combination of factors and multiple paths that affect the effect of farmers' participation in rural environmental governance, which promotes the research of rural environmental governance from a single perspective to an overall multi-dimensional perspective to a certain extent.

KEYWORDS

rural society, farmer participation, rural environmental governance, effect of environmental governance, crisp-set qualitative comparative analysis

1 Introduction

As the core role of rural social life, farmers are the core participants and actors of rural environmental governance. The good governance of the rural environment must depend on the effective participation and active actions of farmers, who are the key factors affecting the effect of rural environmental governance (Li et al., 2020). It has long been believed that “participation leads to a higher degree of sustainable and effective outcomes” (Heinelt, 2002). However existing research on the close relationship between engagement processes and environmental outcomes is empirically established, and it remains unclear why and how this is the case (Scott, 2015). Different fields of research have made various arguments about the pros and cons of participating in environmental outcomes, and have also brought about “tensions between democratic means and environmental goals” (Wong, 2016). This leaves us with logical inconsistencies. The environmental benefits of farmer participation are not automatic but depend on a range of intervention factors (Irvin and Stansbury, 2004). Current studies have not yet revealed the functional path of farmers’ participation in promoting good environmental governance. Only by opening the “black box” of farmers’ participation process (Tan et al., 2024) can we describe a clear path of farmers’ participation in influencing environmental governance performance and provide theoretical support for promoting good environmental governance in rural areas. Therefore, it is very important to explore the core factors of farmers’ participation that affect the performance of rural environmental governance, as well as the configuration patterns among these factors, to develop the theoretical knowledge of public participation and improve the performance of rural environmental governance.

A large number of literature has explained the factors that affect the production of environmental governance performance by farmers’ participation, which can be summarized into the following categories: (1) Dynamic factors. The dynamic factors of public participation in environmental governance are complex and diverse. Good social participation is conducive to reshaping the relationship between government and citizens and improving governance performance, so it is regarded as a new direction of governance innovation (Michels, 2011). To be specific: first, willingness and ability to participate are the basic prerequisites for effective participation in environmental governance. In the process of rural environmental governance, farmers will decide whether to participate in environmental governance based on the assessment of their willingness and ability to participate in environmental governance (Newig et al., 2018), such as the measurement of their income (Zhang et al., 2023). Second, the profit factor is also extremely important. The core purpose of citizen participation in environmental governance is to achieve certain benefit goals, such as obtaining resource support or improving environmental quality (Bandeira and Ferraro, 2017). When the environmental governance work brings obvious benefits to themselves (Friedman et al., 2020; Mageesa et al., 2020), farmers’ support for environmental governance work will be significantly increased. In other words, when there is a strong interest correlation, farmers will take the initiative to improve their environmental behavior and improve the effect of environmental governance (Newig et al., 2023). Third, policy pressure is also a key factor

driving positive environmental behavior in rural areas. When the government issues strict environmental governance policy requirements, especially severe penalties for violations, farmers will have a higher degree of restraint on their environmental behavior (Zhang et al., 2019). In addition, rural China is an acquaintance society, and this social feature also guarantees strong relationships between government agents and farmers, ensuring effective responses and interaction of farmers with environmental governance policies (Peng et al., 2023). Studies have shown that effectively connecting the relationship between citizens and government can help enhance the matching between public service providers and beneficiaries, and improve the efficiency and sustainability of public services (Ackerman, 2004).

(2) Process factors. Process-level factors are crucial for improving engagement outcomes (Reed et al., 2018). On the one hand, diverse and flexible channels of participation are critical to sustaining effective participation. Studies have shown that the low level of environmental knowledge has led to the exclusion of many farmers who are willing to participate in environmental governance work due to the lack of reliable participation channels (Xie, 2016). This has resulted in farmers not cooperating with environmental governance work, resulting in poor environmental governance results (Dong et al., 2023). With the development and popularization of information technology, there are many informal channels of participation (Kostka and Mol, 2017), such as the popular TikTok platform in China. These informal participation channels have the advantages of low cost, high convenience, and unlimited time and space constraints (He et al., 2021), providing farmers with more options for real-time monitoring and feedback on environmental governance behavior. On the other hand, a sound supervision system is crucial to ensure the performance of environmental governance, including formal supervision mechanisms and informal supervision mechanisms such as ethical constraints (Jian et al., 2024). Government departments can use formal supervision mechanisms to regulate farmers’ participation behavior and prevent them from doing environmental damage in the process of participation for personal gain. Informal supervision mechanisms such as the “Red and black list” and “the most beautiful courtyard” can also be established to ensure standardized participation by using social moral forces (Wang et al., 2022). Moreover, punishment is a central element in ensuring the effectiveness of participation. Generally speaking, the harsher the penalty for environmental participation, the higher the compliance with environmental governance norms (Kostka and Zhang, 2018), and the higher compliance means that environmental policies are effectively implemented and good governance results are obtained. For example, increasing the number of fines imposed on the public for environmental violations will significantly improve their environmental governance norms (Zhang et al., 2024).

(3) Guarantee factor. Many factors play a role in ensuring the performance of farmers’ participation in environmental governance, such as government information disclosure. The impact of information disclosure on farmers’ participation in environmental governance is becoming more and more obvious, and reliable and adequate disclosure of environmental information constitutes one of the necessary factors for effective participation (Li et al., 2018). Whether government departments provide complete environmental

governance information, such as environmental monitoring data, policy documents, governance programs, *etc.*, directly affects farmers' behavioral choices in environmental governance (Chen and Ye, 2024). Studies have highlighted that strengthening market information delivery systems will help increase farmers' participation (Omiti et al., 2009). At the same time, some studies have shown that the intensity of government departments' response to environmental governance appeals or queries from the public has a significant impact on the performance of environmental governance participation (Tang et al., 2020). In general, a positive and effective response, such as the development of a response plan or relevant laws and regulations, helps to increase the enthusiasm for environmental governance and improve the effectiveness of participation (Taylor and Lawrence, 2012). Studies have shown that demand response is a key factor in ensuring environmental governance performance, and the lack of an effective response mechanism is the core factor in the decline of environmental governance participation (Gan and Wang, 2020). However other studies have found that strong responses do not necessarily produce good environmental engagement outcomes (Yan and Luo, 2024). On the contrary, it may fall into a public opinion crisis due to improper responses or mistakes, weaken the willingness and enthusiasm of the public to participate in environmental governance, and reduce the participation effect of environmental governance. Therefore, how to grasp the intensity and timing of response is important for maintaining effective environmental participation and strengthening the effect of environmental governance.

It can be seen that existing studies have basically reached a consensus on the causes of farmers' participation in affecting the effect of rural environmental governance, mainly focusing on the dynamic factors, process factors, and guarantee factors. However, it is worth noting that the existing research on the effect of farmers' participation affecting rural environmental governance has not clearly solved the following problems: First, Existing literature has not paid enough attention to the mechanism of farmers' participation in affecting the effect of rural environmental governance. Traditional statistical analysis or a single case study can not distinguish the multiple characteristics of different environmental governance participation, which covers the unique law of farmers' participation in promoting the effect of rural environmental governance. At the same time, these studies have not fully considered the causal relationship between the effect of rural environmental governance and different participation factors, and the occurrence mechanism of good environmental governance participation may be different from that of poor environmental governance participation cases. Therefore, it is necessary to conduct more detailed research on the necessary conditions and causal mechanisms for achieving good environmental governance participation. This study will provide support for improving the overall situation of rural environmental governance from the perspective of public participation. Second, Further studies are needed on the interaction between farmer participation and the effect of rural environmental governance. Existing research is often devoted to analyzing the relationship between a single participation factor and the effectiveness of specific environmental governance. However, they neglect to discuss the interaction between influencing factors. Neither research has revealed the causal relationship

between the specific factors of farmers' participation that affect the effect of rural environmental governance and their combination patterns. In fact, the effect of rural environmental governance is the result of the coupling of multiple factors. A single participation factor may not be sufficient to determine the effectiveness of good rural environmental governance, but a single factor can be coupled with other factors to affect the final outcome of environmental governance. Therefore, in this study, we emphasize the establishment of a causal coupling theoretical framework for farmers' participation in improving the effect of rural environmental governance. Third, the degree of influence of different participation factors on the effect of rural environmental governance is uncertain. Although studies have shown that many factors can influence the ultimate effect of governance, they have not been clear about the extent to which these factors affect the ultimate effect. Therefore, the strength of the role between different participation factors and environmental governance effects has not been answered.

Given the above problems, this study, from the perspective of configuration analysis, uses 15 cases of rural environmental governance in China and a crisp-set qualitative comparative analysis (CsQCA) method to analyze the occurrence path and governance mechanism of farmers' participation in affecting the effect of rural environmental governance, so as to improve the level and quality of farmers' participation in environmental governance. The structure of the paper is as follows: Part 2 is the research design, mainly including the introduction of research methods and ideas, case sources, and variable design. Part 3 is the analysis of the empirical results, including single-factor necessity and sufficiency analysis, configuration analysis, and the production mechanism of good rural environmental governance performance. Parts 4 and 5 provide discussion and conclusions.

2 Research design

2.1 Research methods

Traditional approaches to influencing factors research focus on quantitative analysis, which makes it difficult to explore causality behind complex results. This study uses the qualitative comparative analysis (QCA) method proposed by American sociologist Charles to analyze the causality behind the complex results. QCA is a social science research method based on fuzzy mathematics and set theory, which combines quantitative mathematical statistics analysis with qualitative data analysis. QCA shows that a particular outcome or output (*Y*) is the result of the combined action of several interrelated influencing factors (*X*). That is, a particular outcome may be caused by a single influence or a combination of complex factors. Therefore, QCA combines the advantages of quantitative and qualitative research (Ragin, 1987) and is good at explaining the causal relationships behind complex phenomena. Methodologically, QCA is particularly suitable for multi-case comparative studies in the range 10–60 (Bennett and Elman, 2016). This approach allows for the interpretation of multiple concurrent paths of farmer participation affecting environmental governance effects by combining different conditional variables, which goes beyond the limitations of a single case or a single variable explanation. The

specific operation steps of this method are as follows: Firstly, define the result variables and condition variables, formulate calibration rules, and assign values to variables according to the case facts and theoretical knowledge (Fiss, 2007). Secondly, establish a truth table to present the score combination of condition variables and result variables of each case in detail. Thirdly, using fsQCA software to calculate the truth table, the combination of sufficient and necessary conditions of the result was obtained. For a more detailed software manual, see Ragin (2017).

For the research problem in this paper, QCA has the following adaptability. First, QCA is suitable for the analysis of small and medium-sized sample sizes and can analyze multi-cause concurrent events. Since it is difficult to obtain relevant official data on farmers' participation in affecting the effect of environmental governance, it is impossible to carry out complex statistical studies with large samples, and regression analysis is not applicable. We collected 15 cases of rural environmental governance in China through a combination of official websites and field research. FsQCA software was used to reveal the coupling relationship between different factors, and then to reveal the combination path of farmers' participation in affecting the effect of rural environmental governance. Second, from the existing literature studies, farmers' participation in affecting the effect of rural environmental governance is a complex causal logic involving the interaction of many factors. QCA allows us to show the coupling relationship between different factors through combination condition analysis, and reveal the generation path and mechanism of farmers' participation in affecting the effect of rural environmental governance. Combined with variable characteristics and case situations, this study uses the CsQCA method to explore the core factors and mechanisms of farmers' participation affecting the effect of rural environmental governance. CsQCA is used in this study because the conditional dichotomy required by CsQCA follows the binary logic of "do this or do that", which is a good reflection of real-world decision-making practices (Blackman, 2013) and helps inform decisions in complex systems (He et al., 2024).

2.2 Data sources

The purpose of this study is to explore the factors and paths that affect the effect of farmers' participation in rural environmental governance. Therefore, data selection needs to meet two basic requirements: On the one hand, based on QCA best practices, case selection should follow the principle of "achieving maximum variation on the basis of maximum similarity" (Mahoney and Goertz, 2004), which means diversity of case selection. On the other hand, the cases must meet the requirements of achieving good environmental governance participation, and it is necessary to collect cases of farmers participating in environmental governance and achieving good results. On this basis, the principles of case collection and selection are set up: First, representativeness, cases should achieve good results in a certain field, and be recognized by the local government and the masses. The second is diversity, and cases need to involve different areas of rural environmental governance, rather than focusing on just one area. The third is data availability and comprehensiveness. The selected case data should be as rich and comprehensive as possible, including statistical data, public reports,

academic research literature, official policy texts, and other data related to rural environmental governance.

Following the above principles, we acquire cases in two ways. First, we used effective cases retrieved from the National Typical Cases of Rural Public Services issued by the National Development and Reform Commission, the official websites of local governments, and the Peking University Talisman database as our sampling framework. The initial database included 23 cases, but 10 cases were excluded due to low data availability. We also applied QCA best practices to distinguish between cases and data verifiability criteria, thus excluding three cases that did not meet the requirements. In the end, 10 cases were collected in this way. In QCA analysis, this sample size meets the requirements for small and medium-sized sample analysis (Rihoux and Ragin, 2009). Secondly, the research team conducted research on grassroots ecological and environmental governance in CS, SS, YZ, and LD cities of H Province in June–July 2022 and January–February 2023. Interviews with township leaders, staff, and people familiar with grassroots environmental governance work. Conduct field surveys on local environmental governance and collect information on policy documents, internal data, public data, governance ledgers, and results reports. The research was carried out in the form of semi-structured interviews, open symposia, and individual talks. After interviews and qualitative data collection, five villages were selected as case samples for this study. Therefore, this study finally obtained 15 case samples (see Table 1).

2.3 Variable design

Variables include result variables and condition variables. In this study, the effect of rural environmental governance is taken as the outcome variable. If the case or official report is recognized and selected as a typical governance case at a local or higher level, the governance effect is judged to be good, and the value is 1. On the contrary, if the case is not officially reported and is not selected as a typical case, the governance effect is judged to be poor, and the value is 0. The exploration of the effect of rural environmental governance aims to explore which influencing factors and their combinations can have a positive impact on rural environmental governance by analyzing the conditional variables related to farmer participation.

2.3.1 Condition variable design

Combining case facts and theoretical knowledge base, and fully considering the maneuverability of variables, Select participation ability, interest correlation, the participation channel, supervision & punishment, demand response, and information disclosure as condition variables. The research framework of "dynamic-process-guarantee" in this paper is established, as shown in Figure 1.

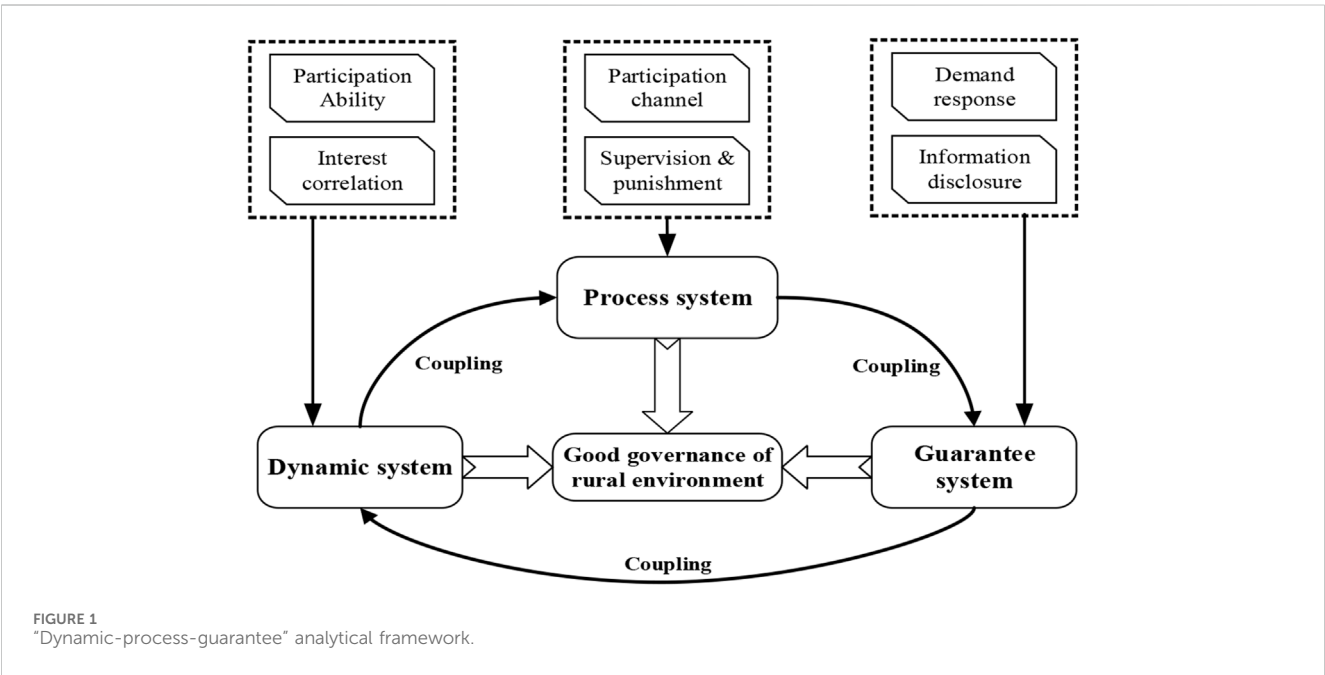
The specific evaluation criteria of condition variables are as follows (see Table 2):

2.3.2 Participation ability

Participation ability is a comprehensive manifestation of farmers' participation willingness and governance knowledge in rural environmental governance. Studies have noted that the willingness and knowledge of the public to participate are the key factors that affect the effect of participation (Diduck and Sinclair, 2002; Fung, 2006), and the education level and value cognition of the participants constitute the core conditions that

TABLE 1 Case list of rural environmental governance.

No.	Case name	Case core source
1	The “three lists” lead the improvement of rural living environment	The Typical Cases of National Rural Public Service
2	“Six insist” painted on the village beauty and a new picture scroll	Hunan Rednet
3	The Party building leads the improvement of the living environment in Pingzhuang Village	Official website of Kunshan Forum
4	Play a good environmental remediation challenge to build an ecological livable environment	The Typical Case of Linyi Rural Revitalization
5	Build a comprehensive governance system for the living environment	The Typical Cases of National Rural Public Service
6	Implement the mass line in a practical way to promote the improvement of rural living environment	Wujiang District Bureau of Agriculture and Rural Affairs
7	Innovate the “nine mechanisms” to achieve the “four changes” to fight the environmental remediation competition	The Typical Case of Rural Living Environment Improvement in Shandong Province
8	“The grid is managed by people, people walk in the grid, and things are done in the grid”	Yixing City Rural Affairs Bureau
9	Fight the “three battles” to help promote rural revitalization	Changzhi Municipal Bureau of Agriculture and Rural Affairs
10	The dream is the water place	“Rural Revitalization in Zhejiang” is a typical case
11	CS City case	The author investigated and collated
12	SS City case	The author investigated and collated
13	YZ City case	The author investigated and collated
14	YY City case	The author investigated and collated
15	LD City case	The author investigated and collated



greatly affect their willingness and knowledge to participate (Otto and Pensini, 2017; Chen and Lin, 2019), thereby determining the level of farmers’ participation ability. *Interest correlation*, when positive and negative externalities are difficult to effectively internalize and calculate, participants’ governance benefits affect their enthusiasm for and participation in public affairs governance (Turner and Quinn, 2005;; Bodin, 2017). In other words, the greater the degree of interest correlation is, the

stronger the willingness and motivation for public participation (Gustafson and Hertting, 2017; Wang et al., 2023). On the basis of the subjective data obtained via email consultation and telephone interviews, the degree of interest correlation between farmers and governance actions in specific environmental governance actions was determined. Then, three subfactors were set, namely, association strength, association type, and harm result.

TABLE 2 Variable setting and assignment standard.

variable type	Variable name	Specific variables	Assignment rules	Score	Example
Outcome variable	Environmental governance effect	-	Officially recognized and selected typical cases	1	Being selected as a typical case of rural public service at the national or provincial level by the government.
			Has not been officially recognized and selected as a typical case	0	Not selected as a typical case of rural public service at the national or provincial level published by the government.
Conditional variable	Participation ability	Education level	Complete compulsory education	If one or more indicators are involved, the value is 1, otherwise it is 0	Farmers have completed compulsory education and clearly believe that the village environment requires collective governance.
		Value cognition	Environmental pollution needs to be treated		Farmers have completed compulsory education but do not believe that the village environment requires collective governance.
	Interest correlation	Correlation strength	A direct threat to vital interests	If two or more indicators are involved, the value is 1, otherwise it is 0	Farmers reported that the garbage pit in front of their houses emits a pungent odor and contaminates their crops.
		Association type	Economic correlation		Farmers believe that the garbage pit in front of their houses has no impact on their production and daily life.
		Hazard result	Directly destroy normal production and life		
	Participation channel	Channel diversity	Both formal and informal channels	If two or more indicators are involved, the value is 1, otherwise it is 0	The government has provided various environmental governance participation channels that align with the needs of local farmers and has offered timely and proactive feedback to their environmental concerns.
		Channel smoothness	Demand feedback can be recognized and received by superiors		
		Channel accessibility	The channel is easy to use and relatively convenient		The government has provided only limited participation channels without considering their relevance, and has been slow in giving feedback to farmers' environmental concerns.
	Supervision & punishment	Supervision intensity	Government, farmers, and third-party monitors are present simultaneously	If one or more indicators are involved, the value is 1, otherwise it is 0	A monitoring system involving the government, farmers, and other supervisory personnel has been established, along with corresponding punitive measures.
		Punishment standard	Establish clear criteria and procedures for punishment		Only a monitoring system involving the government, farmers, and other supervisory personnel has been established, or only punitive measures have been put in place.
	Demand response	Response mode	Proactive response	If two or more indicators are involved, the value is 1, otherwise it is 0	A demand-responsive system targeting farmers has been established, with clearly defined response times or corresponding measures.
		Response speed	Respond effectively within the time limit		A demand-responsive system targeting the village has been established, but without clearly defined response times or measures.
		Response effectiveness)	Targeted response based on reason and evidence		
	Information disclosure	Intensity of publicity	Disclose information in two or more ways	If two or more indicators are involved, the value is 1, otherwise it is 0	Environmental governance policies, funding, and issues are disclosed to farmers through various forms such as informational brochures, website announcements, and leaflets.
		Information integrity	Government disclosure is enough for the public to judge the <i>status quo</i>		Only brief information is disclosed to farmers through internal documents or official website announcements.
		Information validity	Public information is accurate		

TABLE 3 Single factor necessary condition test.

Conditional variables	Good governance effect		Conditional variables	Poor governance effect	
	Consistency	Coverage		Consistency	Coverage
Participation ability	0.750	1.000	~ Participation ability	1.000	0.777
Interest correlation	0.625	0.714	~ Interest correlation	0.714	0.625
Participation channel	0.875	0.875	~ Participation channel	0.857	0.857
Supervision & punishment	0.625	0.555	~ Supervision & punishment	0.428	0.500
Demand response	0.625	0.714	~ Demand response	0.714	0.625
Information disclosure	0.625	0.454	~ Information disclosure	0.142	0.250

2.3.3 Participation channel

Practice has shown that different participation methods produce different effects, and integrating formal and informal forms of participation can achieve better effects on public participation (Johnson, 2010). The participation channel affects the participation effect. The study divides the participation channel into channel diversity, channel accessibility, and channel accessibility. *Supervise & punishment*. The supervision and punishment mechanism of public participation affects the effect of government environmental governance (Huang and Lei, 2021; Yao et al., 2020). In other words, the soundness of the supervision and punishment mechanism of farmer participation affects the effect and quality of farmer participation. In turn, it will have an impact on the government’s environmental governance actions. According to the literature and case data, supervision punishment is refined into supervision intensity and punishment standards.

2.3.4 Demand response

Government response can effectively promote public participation in environmental protection (Wu et al., 2022) and thus promote cooperation in environmental pollution control. Studies have shown that the government responds slowly and that the response effect is relatively poor (Song and Zhang, 2022). This study combines the speed, mode, and effectiveness of government response to judge the efficiency of government response. *Information disclosure*. The more comprehensive the disclosure of environmental governance information is, the more information resources the public can grasp, the more accurately the government’s work and environmental governance status can be understood, and the more actively it can participate in environmental governance (Zhang et al., 2022; Chu et al., 2022). The research is defined by the perception of information disclosure of farmers, including the timeliness, completeness, and effectiveness of information disclosure.

3 Empirical analysis

3.1 Single factor necessity and sufficiency analysis

Necessary and sufficient conditions for calculating results using fsQCA3.1b software. The calculation results are shown in Table 3. A

TABLE 4 Conditional configuration analysis.

Condition variables	Good governance effect				
	I	II	III	IV	V
Participation ability	●	●	●	●	
Interest correlation	Δ	Δ	Δ		
Participation channel		●	●	●	●
Supervision & punishment	●	●			●
Demand response		Δ	Δ	Δ	
Information disclosure	Δ		Δ		
Consistency	1.000	1.000	1.000	1.000	1.000
Original coverage	0.250	0.250	0.250	0.125	0.125
Unique coverage	0.250	0.125	0.125	0.125	0.125
Total consistency	1				
Total coverage	0.875				

necessary condition usually means that the condition variable guiding a particular outcome is always present, and if the consistency level is greater than 0.9, then the condition variable can be considered necessary for a particular outcome (Peer, 2011). When the consistency of a condition variable is between 0.8 and 09, it is considered a sufficient condition for the result variable. The results show that the conditional consistency level of the good governance effect is lower than 0.9, indicating that there is no necessary condition for the good governance effect, but the participation channel (consistency = 0.875) can be regarded as a sufficient condition for good governance effect. At the same time, insufficient participation ability (consistency = 1) is a necessary condition for poor governance results, and limited participation channels constitute a sufficient condition for poor governance results. The necessity analysis results show that the improvement of the effect of farmers’ participation in promoting rural environmental governance is the result of the combination of multiple causes. Therefore, we will conduct an analysis of the conditional configuration next to obtain more information about the path of farmers’ participation in influencing the effect of rural environmental governance.

3.2 Conditional configuration analysis

In this study, we used fsQCA3.1b software to analyze the intermediate solution and simple solution of farmers' participation in producing good environmental governance effects. The statistical analysis results are shown in Table 4. In the analysis results, QCA requires that the consistency of the solution should be greater than 0.8, and the coverage rate should be higher than 0.5. This shows that our calculation results meet the requirements of consistency and coverage. The results show that there are five configurations of farmers' participation in producing good environmental governance effects. The consistency of the five configuration paths is 1, and the coverage is 0.875, indicating that five interpretation paths can explain 87.5% of the case sample. In addition, the core and edge conditions are distinguished based on the union of simplified and intermediate solutions (Lou et al., 2022). In Table 4, the condition variables that appear in both the intermediate solution and the simple solution are the core variables and are represented by “●” in the path. Other condition variables are auxiliary conditions that have relatively little influence on the result variable and are represented by “Δ.” Spaces indicate that the presence or absence of a conditional variable is irrelevant to the result.

Among them, Configuration one shows that participation ability and supervision & punishment play a core role, and interest association and information disclosure play an important auxiliary role. This means that farmers' participation ability and the government's supervision and punishment mechanism are important conditions to promote farmers' active participation in rural environmental pollution control. In Configuration 2, participation ability, participation channel, and supervision & punishment play a core role, while interest association and demand response play an important auxiliary role. This means that farmers, driven by strong participation ability, enter the field of governance through diverse and unimpeded channels of participation. Subject to effective government response and clear rules of engagement, governments and farmers can work together to control environmental pollution. In Configuration 3, participation ability and participation channel play a core role, while interest association, demand response, and information disclosure play a supplementary role. This means that farmers have a strong incentive and willingness to participate, and the government can effectively respond to participation and provide information support. With multiple channels of participation, the interaction between individual needs and government goals can be achieved, and the impetus for collective action can be formed. In Configuration 4, participation channel and supervision & punishment constitute the core conditions for promoting good governance in rural environments, which means that clear and specific supervision and punishment norms are important conditions for ensuring effective participation. In Configuration 5, participation ability and participation channel are the core conditions, and demand response plays an auxiliary role. In addition, weak interest correlation, ineffective regulatory penalties, and insufficient information disclosure also play an important role. This means that when farmers have the ability to participate and the channels for participation are smooth, their participation in environmental governance is not entirely driven by interests. Instead, they are

motivated to respond to the demands of governance. From the perspective of a single condition (horizontal), participation ability and participation channel play a core role in the configuration of multiple conditions, indicating that farmers' participation ability and willingness and participation channel have an important driving effect on their participation in environmental governance. Participation channel, as the core condition, further validates its sufficient condition result in necessity analysis.

3.3 Mechanism for generating good environmental governance effects

Based on the configuration analysis of conditional variables, the mechanism of farmers' participation in improving the effect of rural environmental governance was summarized and refined. According to the five configurations, three mechanisms of farmers' participation in improving the effect of rural environmental governance were extracted. That is, the two-wheel drive mechanism (Path 1) in which dynamic and process factors are coupled to produce good environmental governance effects, the process empowering mechanism (path two and path 5) in which process factors are strongly empowered to produce good environmental governance effects, and the comprehensive support mechanism (path three and path 4) in which dynamic - process - guarantee factors are coupled to produce good environmental governance effects.

- (1) Two-wheel drive mechanism coupled with dynamic and process factors. Configuration one is a typical path that represents the coupling of dynamic factors and process factors to produce good environmental governance effects. The core conditions of this path include participation ability and supervision & punishment, combined with interest correlation and information disclosure as auxiliary conditions. In this mechanism of farmers' participation in improving the effect of rural environmental governance, although farmers lack diversified channels and effective demand response to participate in environmental governance work. However, under the joint drive of strong participation ability, effective supervision & punishment, and moderate interest correlation, farmers can still use limited participation channels to improve the effect of rural environmental governance.

Case 1 is a typical example of the two-wheel drive mechanism. In Case 1, villages served as the basic units for action. Special task forces for improving rural living environments were established by organizing village cadres, stationed work teams, and grid administrators. These groups convened public meetings to solicit feedback and suggestions from farmers, effectively mobilizing them to actively participate in environmental improvement efforts. This significantly enhanced the farmers' ability to engage in environmental governance. At the township level, a three-list system was implemented—comprising a “problem list,” a “responsibility list,” and a “rectification list.” A supervisory task force, organized by the township discipline inspection committee, conducted follow-up inspections and reviews. Tasks that were

completed were checked off the list, while grid administrators who failed to meet rectification requirements were suspended from their duties to focus solely on completing the necessary corrections within a set timeframe. At the village level, a “red and black list” system was introduced. Comprehensive inspections of all natural villages were conducted quarterly, with monthly announcements of the red and black lists at the natural village level, and quarterly updates at the administrative village level. This system continuously improved the standardization of farmer participation in governance and provided institutional support and supervision for effective management. Thus, the combination of moderate participation ability and a system of supervision and penalties serves as a driving force, enabling rural residents to effectively address environmental issues.

- (2) Process empowering mechanism dominated by process factors. The core conditions of this path include participation ability, participation channel, and supervision & punishment, combined with interest correlation and demand response as auxiliary conditions. This shows that even if there is a lack of adequate environmental information disclosure, the combination of strong participation ability, diversified participation channels, effective supervision & punishment can ensure that farmers’ participation can produce good environmental governance effects. Appropriate interest correlation and the government’s response to farmers’ participation appeal play an important role in promoting and assisting.

Case 6 is a typical example of the process empowering mechanism. In Case 6, a special task force for rural living environment improvement was established, composed of stationed village officials and university-graduate village officers. This team was responsible for educating rural residents about the importance of environmental governance and informing them of the specific methods and channels available for participation. This effectively enhanced farmers’ participation ability and clarified the channels for their involvement. Meanwhile, during their visits throughout the villages, the task force also played a dynamic supervisory role by identifying environmental issues and promptly implementing appropriate punitive measures. Additionally, the village organized weekly public clean-up campaigns, engaging all residents in collective efforts to remove waste from public areas. A “Home Beauty Points Supermarket” was also established. In this system, farmers could accumulate points through participation in environmental sanitation improvement activities and “Beautiful Courtyard” initiatives. These points could then be redeemed for daily necessities such as buckets, clothes racks, electric kettles, and laundry detergent. This system subtly linked farmers’ interests with environmental governance. Through the combination of enhanced participation ability, clear participation channels, dynamic supervision & punishment, and interest-based incentives, the village successfully motivated residents to actively engage in environmental governance, thereby achieving effective and sustainable environmental management.

- (3) Comprehensive support mechanism of dynamic-process-guarantee factor coupling. The core conditions of this path include participation ability and participation channel,

combined with interest correlation, demand response, and information disclosure as auxiliary conditions. The comprehensive support mechanism shows that the aggregation of multi-link factor energy is the key to ensuring farmers’ participation in improving the effect of rural environmental governance. As long as participation ability and participation channel are guaranteed, farmers can achieve effective participation with the support of interest correlation, demand response, and information disclosure elements, overcome the difficulties of lack of supervision & punishment, and improve the effect of environmental governance.

All in all, there are three different mechanisms for farmers to participate in improving the effect of rural environmental governance: two-wheel drive, process empowering, and comprehensive support. These three mechanisms indicate that farmers’ participation in improving the effect of rural environmental governance is the result of multi-factorial coupling.

Case 7 is a typical example of the comprehensive support mechanism. In Case 7, although no explicit supervision and punishment system was established at the village level, the local government played a supportive role through multiple channels. It distributed brochures on rural living environment improvement, promoted informative articles via WeChat public accounts, and converted promotional content into audio formats. These were broadcast repeatedly through village loudspeakers, sanitation vehicle speakers, and handheld “mini-speakers” to encourage residents to abandon unhealthy living habits and to familiarize themselves with the various channels and methods for participating in environmental governance. These efforts significantly improved farmers’ environmental awareness and participation abilities. At the same time, the government actively and promptly responded to residents’ concerns about rural living conditions. A three-level response system was established, involving farmers, village cadres, and township officials. In addition to being responsive, the authorities proactively disclosed relevant information to all villages, including policies on rural environment improvement, funding usage, and the status of rectification efforts. This transparency ensured farmers’ right to be informed and to participate. Ultimately, these combined efforts generated an internal motivation among farmers to engage actively in rural environmental governance, resulting in effective management of the village environment.

3.4 Robustness test

The consistency level setting affects the number of logically minimized truth table rows, which in turn affects the result. Schneider and Wagemann (2012) proposed a robustness test by adjusting the consistency level. In this work, the robustness of the results is tested by adjusting the consistency level. If the consistency level between the generated conditional configurations is changed, there is still a clear subset relationship. The results are considered to be document-reliable, even if there are differences in specific configurations. In contrast, the results are not robust. In this study, by reducing the consistency level from 0.85 to 0.8 or

increasing it to 0.9, the consistency level of the global solution did not change significantly, and the configuration did not change significantly. Therefore, after adjusting the threshold of the consistency level, the configuration conclusions of this study did not change substantially, and the results were considered robust.

4 Discussion

This study provides several important insights into how farmer's participation enhances the effectiveness of rural environmental governance. From a configurational perspective, it finds that participation channels are a sufficient condition for achieving good governance outcomes, whereas lack of participation ability is a necessary condition for poor governance outcomes. Other factors—such as interest correlation, supervision & punishment, demand response, and information disclosure—tend to exert influence through interaction with other conditions. This suggests that the effectiveness of rural governance is not determined by a single factor, but rather the result of the interplay among multiple factors, reflecting the complexity of grassroots environmental governance in practice.

4.1 From variables to configurations: a path toward mechanism-based understanding

A key contribution of this study is the shift from isolated variable analysis to a configurational perspective. By constructing a “dynamics–process–support” coupled analytical framework, the study identifies three governance mechanisms: the two-wheel drive mechanism, the process empowering mechanism, and the comprehensive support mechanism. These mechanisms explain why and how farmer participation can improve governance outcomes at a deeper, more systemic level. This mechanistic explanation responds to past criticisms of participation studies for neglecting variable interactions and instead emphasizes the interactive role of participation within a system. The findings show that effective environmental governance does not depend solely on whether farmers are “passively involved” but hinges on the organic interplay among multiple layers of factors. This marks a transition from studying “influencing factors” to exploring “mechanisms”, providing both theoretical reference and practical guidance for farmer participation in environmental governance.

Furthermore, this study responds to the tension in participatory governance literature between “participation quality” and “governance effect.” For example, some configurations yield good results even with limited information disclosure, while others require robust information support. This suggests that participation quality is relational and context-dependent rather than absolute. Its effect depends on how it interacts with other governance dimensions. This echoes the view that participatory practices exist along a continuum between democratic and technocratic governance (Bäckstrand, 2006). As the literature increasingly shifts toward co-governance models (Ansell and Gash, 2008), governance effect ultimately depend not on the quantity of participation but on its quality, responsiveness, and institutional embeddedness.

4.2 Participation channels and participation quality

The critical role of participation channels in this study supports prior findings that accessible and diversified participation pathways are the foundation of meaningful involvement. Nearly all configurations that led to effective governance outcomes emphasized the importance of participation channels. This finding aligns with Arnstein's (1969) “Ladder of Citizen Participation” theory, which posits that participation becomes substantive—not merely symbolic—only when institutional design guarantees meaningful power-sharing mechanisms. Existing research has shown that farmers' internet access (He et al., 2021), environmental knowledge (Zhang et al., 2022), and access to usable participation channels significantly enhance their willingness and effectiveness in engaging with environmental governance. Chen and Liu (2022) also noted that a lack of clear participation methods is a key barrier to civic involvement in environmental governance. Furthermore, when farmers are involved in more critical domains and political activities, urban-rural environmental governance receives stronger support (Huang et al., 2024).

For instance, in Case 5, the local government used home visits, media outreach, and WeChat platforms to diversify participation methods, enabling more inclusive governance. This institutionalized design allowed farmers to truly engage in governance processes, aligning with Fung's (2006) three key elements of participation quality: degree of communication, redistribution of power, and representativeness.

4.3 Participation ability and outcome quality

The study finds that a lack of participation ability is a necessary condition for poor governance outcomes, reinforcing the foundational role of ability building for effective participation. Even when participation opportunities exist in form, farmers who lack environmental literacy, technical knowledge, or organizational skills often fail to translate participation into governance influence (Meng et al., 2022). This indicates that “having opportunities to participate” does not equate to “effective participation”. This distinction echoes the theory of participatory governance that differentiates between nominal and substantive participation. It also aligns with Rowe and Frewer's (2000) argument that many participation mechanisms fail not because of poor design but because the public lacks the knowledge and skills to engage meaningfully. A critical solution to this issue is for governments to enhance information disclosure and promote environmental policy awareness (Yang et al., 2022).

For example, organizing diverse environmental awareness campaigns and tailoring strategies to farmers' specific characteristics (Yu et al., 2024) can strengthen their capabilities and willingness to participate, ultimately improving governance outcomes. Some studies further reveal that as farmers' participation abilities improve, the influence of social networks and norms on participation behavior diminishes (Wang et al., 2022), highlighting the central role of ability in sustaining governance outcomes. Such capacity-building efforts enhance

environmental literacy, enabling more impactful participation. This aligns with the theory of deliberative democracy by Dryzek (2000), which emphasizes informed civic participation as a prerequisite for effective governance. Fischer (2000) also argues that better-informed participants are more likely to make sound judgments, thereby improving the quality of environmental governance.

4.4 Interactive catalysts

Although factors such as interest correlation, supervision & punishment, demand response, and information disclosure are not individually sufficient to drive effect of environmental governance, they serve as important interactive catalysts. Their effectiveness depends on how they are embedded within the overall participation mechanism. This study finds that interest correlation acts as a catalyst for encouraging farmer participation and enhancing governance outcomes. Including key stakeholders with a direct interest in environmental governance (Yao et al., 2020; Sun et al., 2016) can help mitigate NIMBY conflicts and promote policy implementation. Field research from several cases showed that the stronger the interest relevance, the greater the farmers' motivation to engage. For instance, in Case 11, farmers were more inclined to participate in addressing pollution near their homes but showed lower willingness to act on issues in public areas.

Additionally, the study reinforces the positive role of supervision & punishment in improving governance effect. In Case 1, the “Red-Black List” system reinforces behavioral constraints and a sense of responsibility, aligning with Ostrom's (1990) institutional arrangement of “monitoring and graduated sanctions” in the management of common-pool resources. It also finds that the effects of responsiveness and information disclosure must be understood in conjunction with other factors. This partially addresses scholarly debates over the uncertain effects of governmental responsiveness (Yan and Luo, 2024), suggesting that such effects depend on capabilities and participation channels.

5 Conclusion

The limited number of studies on farmers' participation in improving the effectiveness of rural environmental governance has left researchers and practitioners seeking evidence-based knowledge to achieve effective rural environmental governance with little help. This study used qualitative comparative analysis to explore the factors and configurations of farmers' participation in improving the effectiveness of rural environmental governance and obtained some insights. Participation channel is the sufficient condition to obtain the good effect of rural environmental governance, and the lack of participation ability is the necessary condition to lead to the poor effect of rural environmental governance. There are five ways and three mechanisms of good rural environmental governance (two-wheel drive mechanism, process empowering mechanism, comprehensive support mechanism). Factors such as interest correlation, supervision & punishment, demand response, and information disclosure play a

supporting role in different paths to produce good environmental governance effects. The specific extent to which these elements play a role depends on their combination with other elements. These findings deepen our understanding of the effects that lead to different levels of rural environmental governance.

The important contribution of this paper is to explore the causal chain of farmers' participation in improving the effect of rural environmental governance. Given the complexity of multiple factors and their interactions, the current literature has a limited understanding of this. This study provides new ideas by exploring related conditions and configurations. Furthermore, through an in-depth analysis of rural cases in China, this study reveals public participation practices in non-Western contexts, enriches our understanding of the effectiveness of farmers' participation in environmental governance in various situations, and makes contributions to the governance and policy literature.

As part of the theoretical construction, future studies should validate the results of this research. This is important because the commonly used approach of “systematically comparing a moderate number of cases while maintaining acceptable complexity” (Gerrits and Verweij, 2018) has limitations in terms of generalizability. Although the selection of 15 well-documented cases is both theoretically and empirically justified, the small sample size inevitably constrains the applicability of the findings across China's diverse rural contexts. Rural areas in China differ significantly in geographical, institutional, economic, and social dimensions, which may influence how various combinations of participation-related factors contribute to governance outcomes. Therefore, future research is encouraged to conduct cross-provincial or cross-regional comparative studies to examine whether and how these causal configurations hold under different contextual conditions. Expanding the scope of case samples, incorporating a wider variety of rural settings, and combining large-sample statistical analysis will help verify or revise the research conclusions and enhance the robustness and external validity of the findings. In addition, further exploration is needed into how the strength of interest correlation, the level of information disclosure, and varying degrees of government supervision may differentially affect the actual impact of farmers' participation in environmental governance. These efforts will contribute to refining the proposed “dynamic-process-guarantee” framework and offer more nuanced, context-sensitive guidance for improving rural environmental governance through farmer participation.

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

CF: Writing – original draft, Writing – review and editing, Conceptualization, Data curation, Methodology, Software, Formal

analysis, Resources, and Visualization. TL: Formal Analysis, Resources, Validation, Writing – review and editing. LC: Formal Analysis, Investigation, Validation, Writing – review and editing. FZ: Conceptualization, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review and editing.

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