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Resilience and intentions of fishermen transitioning to ecological farming: insights from China's Yangtze River basin

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Introduction: To ensure the protection of aquatic ecosystems and fishery resources, while establishing a sustainable mechanism for the transformation of livelihoods that emphasizes ecological farming (leveraging the principles of ecological coupling and symbiosis to achieve harmonious integration between cultivation and breeding), a three-dimensional framework of buffering, self-organization, and learning has been developed based on the theory of "livelihood resilience." "Resilience" encapsulates the ability of fishing communities (or individuals) to withstand disturbances (buffering), reconfigure themselves (self-organization), and adapt or enhance their circumstances through experiential learning (learning abilities).

Methods: The study examines the extent of livelihood resilience in relation to fishing ban, as well as the readiness of various types of fishermen to embrace ecological farming under different incentive structures. It also simulates the varying willingness to adopt ecological farming across diverse environmental contexts within China.

Results: The results indicate that: (1) Self-organization ability, particularly the emphasis on subsidy benefits and policy awareness, could independently lead to interpretive outcomes. (2) There are three pathways that can motivate fishermen to adopt ecological farming: self-organization-dominant, self-organization-learning driven, and buffering-learning driven. Concurrently, there are three categories of factors that impede the enhancement of fishermen's willingness to engage in ecological farming: learning inhibition, self-organization-learning inhibition, and buffering-self-organization inhibition. (3) Under specific conditions, self-organization ability can be substituted by the conditional combination of the other two abilities to bolster the willingness of fishermen to adopt, in a manner akin to "all paths leading to the same destination." (4) Heterogeneity analysis demonstrates that livelihood resilience exerts a more significant influence on the willingness of fishermen in the Yangtze River Basin to participate in ecological farming, particularly in areas with lower economic development levels. Moreover, this resilience has a more pronounced effect on the intentions of older generations.

Discussion: This study offers a novel theoretical framework applicable to ecological farming practices for retired fishermen, operating within a livelihood resilience scale, accompanied by regional heterogeneity support and theoretical guidance for the promotion of sustainable livelihoods.

KEYWORDS

fishermen quitting fishing, fishing-ban policy, livelihood resilience, ecological farming, adoption willingness

1 Introduction

The imposition of a decade-long fishing prohibition on the Yangtze River constitutes a pivotal decision by the Central Committee of the Communist Party of China and the State Council (Han et al., 2020). This decision is predicated on the consideration of long-term strategic interests and the aspiration to secure a more prosperous future for posterity (Gao and Sun, 2023). It signifies a notable advancement in the conservation and administration of significant river systems (Liu et al., 2023; Zhang Y. et al., 2024). The “No. 1 Central Document” released in 2021 underscored the necessity of ensuring the effective enforcement of this extended fishing prohibition by providing requisite support to retired fishermen (Gao et al., 2025). Since the comprehensive rollout of the “ten-year fishing prohibition policy,” ~164,500 riverine fishermen requiring re-employment have been afforded necessary assistance, and around 221,800 eligible retired fishermen have been guaranteed access to insurance coverage (Wang et al., 2022a,b). The policies facilitating the occupational transition for these fishermen integrate the principles of “supporting industries—supporting jobs—supporting entrepreneurship—providing safety nets.” This strategy is designed to augment their competitiveness in the job market and assist them in securing alternative means of livelihood. As indigenous people in Yangtze River basin, after fishermen come ashore, their livelihoods and environment undergo significant changes, and their adaptation to the new identity remains a work in progress. Fishing ban in the Yangtze River has resulted in fishermen losing their primary means of subsistence. During the transitional period between the implementation of the ban and shifting to alternative occupations, fishermen are particularly vulnerable to disruptions in their livelihood chain. Although various policy-driven economic compensations may provide some short-term relief by partially substituting for former fishing incomes, this approach is unlikely to ensure long-term sustainability due to a lack of viable livelihood options. An indigenous problem is relying solely on post-ban economic subsidies may not be sufficient for retired fishermen to maintain a sustainable living, potentially exacerbating conflicts with ecological environments. Therefore, there is an urgent need to identify a livelihood transformation approach that not only facilitates simple operations to help fishermen quickly restore their livelihoods but also minimizes environmental energy consumption. The merits of engaging in ecological farming livelihoods are evident in their minimal capital investment prerequisites, high potential for sustainability, and suitability for fishermen characterized by advanced age and lower educational attainment (Han et al., 2020; Chen et al., 2021). Such initiatives not only expedite the improvement of fishermen’s adaptability but also foster rural revitalization and wealth creation within fishing communities. Additionally, they have the capacity to convert adverse environmental impacts into positive ecological outcomes, thereby propelling eco-friendly development. According to ongoing research tracking the effects on Yangtze River fishermen, government initiatives are concentrated on uncovering inherent potentials within the agricultural and fisheries sectors (He et al., 2023). For those inclined to transition into ecological farming practices, specific policy incentives are provided, including provisions regarding land contracting or transfer arrangements. Furthermore, financial incentives such as adjusted guarantee

conditions and interest subsidies are extended (Liu et al., 2021; Gao and Liu, 2022). Through the promotion of agricultural entities, the reinforcement of production enterprises, the creation of distinctive brands, and other strategies (Lei et al., 2022; Xu and Xu, 2024), the advancement of ecological farming practices is being comprehensively pursued while exploring applications for these models within programs aimed at transitioning retired fishermen into new employment opportunities.

Acceptance challenges are particularly pronounced among individuals with limited risk tolerance, whose objective resource allocations, policy awareness, and information acquisition capabilities constrain their future livelihood decisions. The technical threshold inherent in ecological farming further complicates matters, as it necessitates a comprehensive application of fertilization and pest control techniques. The stress induced by fishery bans, coupled with unfamiliarity with policies and skill deficits, can result in extended psychological adjustment periods for fishermen. A deficiency in confidence regarding career transitions often impedes effective engagement with ecological farming models and reduces their inclination for sustained participation. The livelihood status of fishermen is not only contingent upon the extent of external disturbance pressures but also on their personal resilience and capacity for recovery from resultant adversities. Livelihood resilience pertains to the aptitude of individuals to sustain and enhance their livelihood wellbeing amidst external interventions (Lecegui et al., 2022). As an integral component of sustainable livelihood theory (Chambers and Conway, 1992), it concentrates on the dynamic evolution process and mechanisms of livelihoods, emphasizing the strategic utilization of limited resources by farmers to adjust and adapt to external disturbances. This theoretical framework provides a foundation for the sustainable development of farmers’ livelihoods and is extensively utilized in the investigation of rural poverty (Ghazali et al., 2023). The theoretical framework of livelihood resilience can be categorized into three primary groups: a singular framework centered on the relationship between livelihood capital formation and community disaster recovery (Mayunga, 2007), a multidimensional analysis framework emphasizing resilience and adaptability (Nyamwanza, 2012), and a comprehensive analysis framework encompassing buffering, self-organization, and learning capabilities (Sadik and Rahman, 2009). The application of the livelihood resilience theory is predominantly in the domains of environmental protection and rural poverty alleviation, including assessments of livelihoods in the context of poverty alleviation relocations (Liu et al., 2020), measurements of farmers’ livelihoods in impoverished areas (Fan et al., 2022), and examinations of the factors influencing multidimensional poverty (Li et al., 2022). In this study, livelihood capital is utilized as the primary indicator of buffering ability, and the framework is constructed from the perspectives of the actors themselves and their interactions with social organizations, thereby establishing a livelihood resilience assessment system that emphasizes buffering ability, self-organization ability, and learning ability (He and Chen, 2022). Given that fishermen’s willingness to engage in farming is influenced by various factors such as capital, policy, and society, the concept of livelihood resilience can more profoundly elucidate the multifaceted determinants of their choices and reflect the dynamic impact of structural

disparities on their willingness to adopt. The perception of high-value ecological farming has the potential to alter individuals' behavioral states. Fishermen are pivotal participants in the selection of livelihood strategies and engagement in farming practices. Consequently, it is imperative to enhance individuals' perceptions of ecological farming. The internal transformation of fishermen's perceptions regarding ecological farming can externalize their participation in standardized cultivation and large-scale aquaculture endeavors. Through this approach, they can diversify their livelihoods, augment their adaptability and transformative capacities, and bolster their resilience against risks. Therefore, adopting fishermen's livelihood resilience as a focal point holds practical significance in determining whether resilience (buffering-self-organization-learning) influences fishermen's intentions to adopt farming practices, and in promoting the further application and dissemination of this model.

The utilization of existing resources, as elucidated by Zheng et al. (2020) and Wu et al. (2024), encompasses four principal dimensions: technological investment, information exchange, social relations, governmental support, and transformation opportunities. Scholarly inquiries have delved into the determinants of the adoption intention for ecological farming, focusing on the facets of livelihood capital, neighborhood communication, information exchange, and skill acquisition. Liu et al. (2019a) discerned that the extent of capital owned by farmers exerts a significant influence on their ecological intentions and behaviors. Wang et al. (2022a,b), through an analysis centered on the triad of "information capability-perceived ease-farming willingness," ascertained that farmers' information capability bears a significant positive correlation with their inclination toward farming. Furthermore, Liu et al. (2019b) identified that observational learning within the community and the sentiments engendered by communication can markedly and positively augment farmers' readiness to embrace integrated planting and breeding technologies. Additionally, Zheng and Liu (2022) highlighted that the subjective psychological element of policy cognition can substantially heighten rural residents' inclination toward agricultural production. The construct of livelihood resilience pertains to individuals' capacity to leverage inherent resource endowments to mitigate the effects of external disturbances. This entails the utilization of self-organization and learning competencies to devise adaptive strategies that sustain or elevate prevailing livelihood standards (Zhang D. et al., 2024; Zhang Y. et al., 2024). While safeguarding livelihood capital, this approach also acknowledges the subjective agency of fishermen, thereby remedying deficiencies in extant research. Consequently, the integration of livelihood resilience into the examination of fishermen's willingness to adapt to fishing restrictions along the Yangtze River offers a more comprehensive elucidation of the formation logic behind this willingness to adopt. Prevailing studies have predominantly concentrated on the isolated influence of various conditions on the adoption intention of ecological farming, with scant consideration given to the amalgamation of subjective and objective conditions. Given its complexity, the ecological cultivation inclination of retired fishermen necessitates the contemplation of the synergistic effect of multiple variables across diverse competencies and levels. Traditional regression analysis, which scrutinizes the isolated effects of individual

variables or, at best, the mediating effects of three variables, proves inadequate for explicating the intricacies of ecological farming inclination. The fuzzy set qualitative comparative analysis (fsQCA) methodology, grounded in a holistic analysis of multifactorial configurations, emerges as an efficacious tool for investigating complex, asymmetric, and multifactorial causal relationships. Necessary Condition Analysis (NCA) is specifically tailored to scrutinize necessary relationships and endeavors to rectify the limitations of the Fuzzy Set Qualitative Comparative Analysis (fsQCA) method in discerning necessary conditions. Hence, NCA is utilized to substantiate findings derived from conventional fsQCA necessity analyses. This study employs Necessary Condition Analysis (NCA) and Fuzzy Set Qualitative Comparative Analysis (fsQCA), predicated upon the analytical framework of livelihood resilience theory—encompassing "buffering, self-organization, and learning"—to investigate the configurations and mechanisms that engender regional disparities in fishermen's inclination to adopt ecological farming. The research objectives are threefold: (1) To delineate the configurations of conditions that either foster or impede fishermen's inclination to adopt ecological farming, achieving a common objective; (2) To ascertain whether there exist differentiated propelling pathways for fishermen's inclination to adopt ecological farming across disparate regions; (3) Under specific conditions, to determine if there are equivalent combinations of conditions that can amplify fishermen's adoption inclination.

2 Research perspectives and framework

2.1 Research perspectives: the theory of livelihood resilience in the context of the Yangtze River fishing ban

The concept of livelihood resilience pertains to the capacity of individuals and familial units to endure disturbances, preserve fundamental systems and practices via organizational efforts and the acquisition of knowledge (Bu et al., 2024; Huang and Bruemmer, 2017; Liu et al., 2020; Chen et al., 2025). The prohibition of fishing activities in the Yangtze River has presented substantial challenges for fishermen seeking alternative employment avenues, thereby illuminating two distinct dimensions of "livelihood resilience": dependency on resources and employment pathways. On one hand, the specialized nature of the fishing industry and the pronounced reliance of fishermen on natural resources have resulted in significant ecological repercussions upon cessation of resource exploitation, rendering the transition to alternative livelihoods particularly arduous. On the other hand, the employment trajectories of fishermen diverge from those of farmers and herders. The demographic composition of the fishing community tends to be older, with limited alternative survival skills; apart from their expertise in fishing, they are often bereft of other specialized competencies. Consequently, the adaptation to novel concepts or the mastery of practical technologies necessitates a substantial temporal investment (Thulstrup, 2015). In comparison to farmers and

herders, fishermen are confronted with more precarious livelihood conditions. Thus, the establishment of enduring mechanisms requires not only governmental support in the form of subsidies and enhanced social security for “life-sustaining” aid but also necessitates that fishermen themselves surmount competitive mentalities while focusing on the topology of social networks and the acquisition of technical skills to bolster their “self-reliance” capacities. The provincial and municipal administrations along the Yangtze River have predominantly continued to implement the strategies and practices honed during the battle against poverty alleviation. They are enacting measures such as pinpointing key beneficiaries, offering public welfare positions, promoting policies for “fishing to aquaculture,” providing skills training for fishermen, offering entrepreneurial guidance and follow-up services, and incorporating employment transition rates into grassroots work evaluation metrics. These initiatives aim to ensure that fishermen can effectively transition out of their former vocations, attain stability in their new roles, and ultimately achieve prosperity. Correlating livelihood resilience with the willingness to choose a livelihood enables a dynamic evaluation of fishermen’s ability to revert to their original state while providing a deeper understanding of the underlying rationale behind their cognitive processes.

This study utilizes the theoretical framework of livelihood resilience to scrutinize the policy context of the Yangtze River fishing prohibition in conjunction with the inclination of retired fishermen to embrace ecological farming practices. The determinants influencing the adoption intentions of “farming-centric” livelihood strategies among retired fishermen in representative provinces along the Yangtze River are classified into three principal abilities: buffering ability, self-organization ability, and learning ability.

2.1.1 Buffering ability

Fishermen depend on their inherent resources to mitigate external risks, encompassing five categories of capital: natural, physical, social, financial, and human. Livelihood capital constitutes the essence of their subsistence, and its characteristics and conditions are pivotal determinants of the fishermen’s intentions regarding their livelihood choices (Chen et al., 2020). This study integrates various manifestations of livelihood capital into a unified variable to examine the foundational elements influencing fishermen’s inclination to participate in ecological farming.

2.1.2 Self-organization ability

The integration of fishermen into the local societal fabric and their adaptation to institutional and policy frameworks underscore the significance of stakeholders’ direct engagement. This encompasses three principal conditions: the accessibility of subsidies and benefits for ecological farming, awareness of farming policies, and the extent of trust among neighbors. Participation in ecological farming necessitates support mechanisms, including rewards and subsidies, which objectively influence fishermen’s inclination to adopt such practices. Governmental investment in resources is crucial for providing various forms of support, such as pension and medical insurance subsidies, transitional

living allowances, and agricultural labor assistance, ensuring that fishermen experience a sense of security backed by guaranteed support. As decision-makers, the formation of fishermen’s subjective intentions is intrinsically linked to their comprehension of policies (Shang and Yang, 2021). The depth of their understanding of specific aspects of ecological farming policies—including content, implementation pathways, and effectiveness—substantially affects their preferences for livelihoods. Additionally, extant research indicates that rural Chinese villagers sustain interactions grounded in personal relationships, which cultivate trust and emotional bonds. This fosters a sense of identity and belonging, encouraging pro-social motivations among villagers (Lu and Zhang, 2021). Broadly speaking, fishermen with robust neighborly trust can readily access information pertaining to ecological farming through social networks. This facilitates employment preferences and mitigates employment risks. Consequently, this paper concentrates on investigating the potential influence of government subsidy accessibility, fishermen’s policy awareness levels, and the degrees of neighborly trust on their willingness to engage in farming practices.

2.1.3 Learning ability

The capacity of fishermen to obtain information and technology, as well as to direct their production and daily activities, specifically includes two subordinate conditions: the initiative of fishermen in engaging in pertinent technical training and the extent of information exchange among them. Considering that retired fishermen have long depended on fishing, they frequently possess limited skills and require a longer period to adapt to novel concepts. In contrast, ecological farming necessitates a substantial body of knowledge and adept operational skills. Should fishermen have not partaken in relevant training, it may impede their inherent motivation to engage in it. On the other hand, active engagement in training can contribute to the development of a more comprehensive understanding (Xie et al., 2022), diminish the uncertainties associated with the application of new skills, and thus eradicate adverse selection phenomena in ecological farming. Additionally, information is characterized by its timeliness and varying degrees of transparency, which can result in asymmetries. Such asymmetries exacerbate the costs associated with acquiring information and impact both the precision of government policies concerning farming and the proactive inclination of fishermen toward changes in their livelihoods. Fishermen exchange information via various resource-sharing platforms, thereby accelerating the flow of information and expanding the employment radius of their labor force. This interaction effectively stimulates their potential inclination to engage in ecological farming activities (Yang and Zhao, 2020).

2.2 Research framework

The aforementioned six secondary conditions underscore the significance of livelihood capital as the cornerstone for fishermen to attain favorable livelihood outcomes. Subsidies play a pivotal role in shaping fishermen’s subjective inclinations toward the adoption of ecological farming methodologies, whereas policy awareness is indicative of their comprehension of ecological compensation

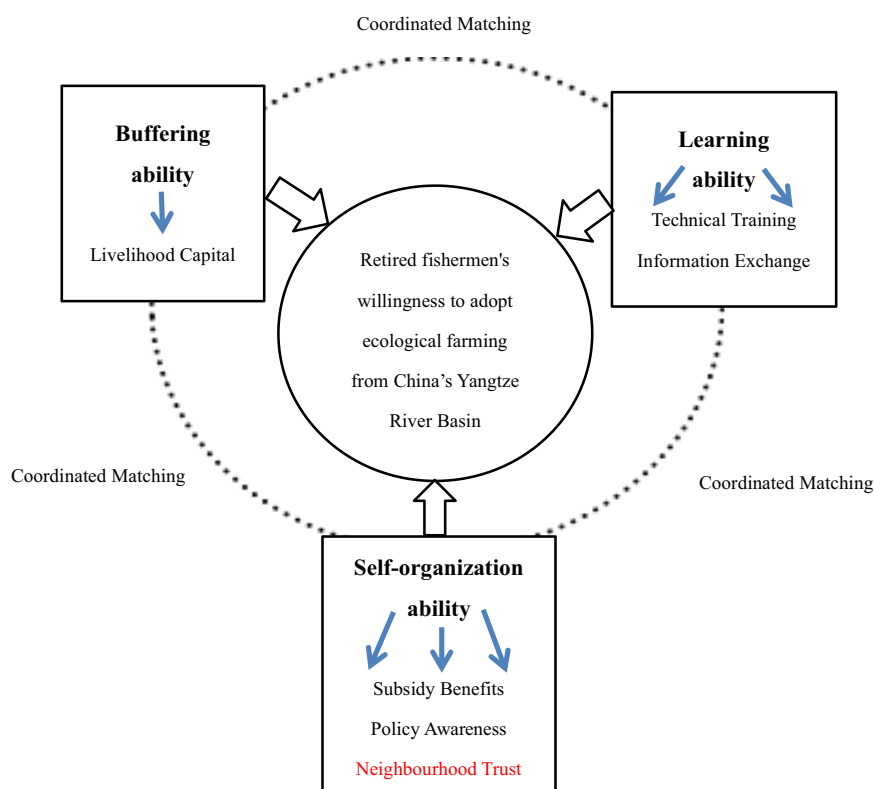


FIGURE 1
Research framework.

and agricultural policies. The extent of neighborhood trust and information exchange reflects the scope of social networks that influence fishermen's inclination to participate in farming activities. Technical training is emblematic of fishermen's eagerness to engage proactively in the acquisition of farming knowledge. These six variables exhibit a logical interrelation. From a configurational standpoint, conditional variables interact synergistically with outcome variables to collectively exert their influence. This paper, situated within the context of fishing prohibitions along the Yangtze River and concerning the resilience of livelihoods, integrates factors such as capital accumulation, subsidy attainment, policy comprehension, and information technology that impact fishermen's inclination to engage. A three-dimensional configurational framework, encompassing buffering, self-organization, and learning, is established (Figure 1) to empirically investigate how these three abilities can foster fishermen's inclination to embrace ecological farming through their interconnected interactions.

3 Materials and methods

3.1 Research methods: the combination of necessary condition analysis and qualitative comparative analysis of fuzzy sets

The Fuzzy Set Qualitative Comparative Analysis (fsQCA), introduced by Ragin during the 1980s, is a research methodology

that utilizes Boolean algebra and set theory to conduct comparative case analyses and ascertain the “synergistic effects” of interactions among multiple conditional variables on specific outcomes (Ragin, 1987). The amalgamation of fuzzy sets with qualitative comparative analysis enables a more refined examination of variations in degrees or partial membership (Tan et al., 2019). Fuzzy Set Qualitative Comparative Analysis (fsQCA) permits a comprehensive examination of the driving pathways that influence fishermen's inclination to embrace ecological farming practices. This methodology recognizes the complete equivalence of different antecedent configurations without requiring standardized treatment across varying levels of antecedent variables, rendering it appropriate for cross-level analyses as demonstrated in this paper (Wang et al., 2014). The Necessary Condition Analysis (NCA) is a novel research methodology founded on complex causal premises. It not only identifies the necessary conditions for outcomes but also quantitatively assesses the effect size of these necessary conditions and evaluates the magnitude of bottlenecks that constitute necessary conditions (Zhu et al., 2022).

Theoretical perspectives and research frameworks suggest that the interplay of buffering, self-organization, and learning abilities synergistically influences fishermen's inclination to embrace ecological farming practices, as their interconnected dynamics foster a multitude of concurrent causal relationships characterized by various logical combinations. Conventional regression analysis methods, which concentrate on linear causal relationships, are constrained in their capacity to clearly delineate the intricate configurational effects among antecedent factors (Huang

and Sheng, 2024). Fuzzy Set Qualitative Comparative Analysis (fsQCA) accentuates the configurations of antecedent conditions that result in particular outcomes, exhibiting features such as relational asymmetry, multiple equivalences, and causal complexity. Nonetheless, since fsQCA evaluates the necessity or sufficiency of antecedent conditions exclusively from a qualitative standpoint, it can impact the precision of identification. Although Necessary Condition Analysis (NCA) is limited to identifying necessary conditions, its methodology provides a greater depth and accuracy by quantitatively depicting “the extent to which a condition must be fulfilled to be deemed necessary for achieving a specific level of outcome,” thus effectively addressing the inherent limitations of qualitative comparative analysis (Luo and Song, 2025). This paper adopts fuzzy-set qualitative comparative analysis (fsQCA) as the principal research method for examining sufficient conditions, while employing NCA as a supplementary approach to investigate the inclination of retired fishermen to adopt ecological farming models within the tripartite configurations of buffering, self-organization, and learning.

3.2 Data collection, measurement, and calibration

3.2.1 Data collection

The dataset originates from the 2021 “tracking survey of fishermen impacted by the Yangtze River fishing ban.” The sample consists of 409 households of retired fishermen from 38 cities and counties in Sichuan, Chongqing, Hunan, Jiangxi, Anhui, and Jiangsu. Following the exclusion of questionnaires with incomplete information, a total of 397 valid samples were procured, yielding an effective sample rate of 97.07%. The geographical distribution of the sampled fishermen is depicted in Table 1. As for the provincial distribution, the percentages are as follows: Hunan Province constitutes 18.89%, Jiangsu Province 27.21%, Jiangxi Province 11.84%, Anhui Province 13.85%, Sichuan Province 13.6%, and Chongqing City 14.61%. Table 2 quantifies the correlation coefficients among various factors influencing fishermen’s inclination to adopt ecological farming practices. It indicates that all conditional variables are significantly correlated with the outcome variable, corroborating our research hypotheses.

TABLE 1 Geographical distribution of the sample retired fishermen from China’s Yangtze River.

Provinces	City/district/county	Sample size	Percentage (%)	Provinces	City/district/county	Sample size	Percentage (%)
Hunan (75)	Yuanjiang	11	0.15	Jiangsu (108)	Sihong	21	0.19
	Hanshou	10	0.13		Xuyi	16	0.15
	Xiangyin	9	0.12		Jingjiang	13	0.12
	Anxiang	8	0.11		Yixing	11	0.10
	Heshan	7	0.09		Wujiang	10	0.09
	Taojiang	7	0.09		Jiangdu	9	0.08
	Junshan	6	0.08		Wujin	8	0.07
	Miluo	5	0.07		Hongze	7	0.07
	Nan county	5	0.07		Jiangyin	7	0.07
	Liuyang	4	0.05		Wuzhong	6	0.06
	Linxiang	3	0.04				
Chongqing (58)	Yunyang	14	0.24	Jiangxi (47)	Poyang	17	0.36
	Hechuan	12	0.21		Duchang	14	0.30
	Jiangjin	10	0.17		Yugan	9	0.19
	Fuling	9	0.16		Xinjian	7	0.15
	Yubei	8	0.13				
	Beibei	5	0.09				
Sichuan (54)	Fushun	37	0.69	Anhui (55)	Anqing	16	0.29
					Wuhu	15	0.27
					Huangshan	10	0.18
					Tongling	8	0.15
	Ziyang	17	0.31		Chizhou	6	0.11

** $p < 0.01$, two-tailed test.

TABLE 2 Correlation factors influencing retired fishermen’s willingness to adopt ecological farming.

Variables	Willingness to adopt	Livelihood capital	Subsidy benefits	Policy awareness	Neighborhood trust	Technical training	Information exchange
Willingness to adopt	1						
Livelihood capital	0.257**	1					
Subsidy benefits	0.344**	0.321**	1				
Policy awareness	0.308**	0.209**	0.442**	1			
Neighborhood trust	0.469**	0.312**	0.304**	0.230**	1		
Technical training	0.462**	0.238**	0.121**	0.220**	0.323**	1	
Information exchange	0.404**	0.224**	0.399**	0.309**	0.356**	0.275**	1

***p* < 0.01, two-tailed test.

TABLE 3 Retired fishermen’s buffering ability—evaluation index of livelihood capital.

Target Layer	Guideline layer	Sub-guideline layer	Index level	Indicator meaning and score assignment	Weight
Livelihood resilience	Buffering ability	Natural capital (N)	N1 Aquaculture area of pond(mu)	N1 = 0(1); 0 < N1 ≤ 1(2); 1 < N1 ≤ 3(3); 3 < N1 ≤ 5 (4); N1 > 5 (5)	0.120
			N2 Cultivated land and forest area (mu)	N2 = 0(1); 0 < N2 ≤ 1(2); 1 < N2 ≤ 3(3); 3 < N2 ≤ 5 (4); N2 > 5 (5)	0.143
		Physical capital (P)	P1 Types of household durable goods	Types of household appliances, common or medium to large vehicles owned: P1 = 0(1); P1 = 1(3); P1 = 2(5)	0.125
			P2 Per capita residential area	Ratio of residential area to household size: P2 < 10 (1), 10 ≤ P2 < 20 (2), 20 ≤ P2 < 30 (3), 30 ≤ P2 < 50 (4), P2 ≥ 50 (5)	0.070
		Social capital (S)	S1 Degree of familiarity with current neighbors after retiring	Very unfamiliar (1); not very familiar (2); general (3); relatively familiar (4); very familiar (5)	0.065
			S2 Number of contacts with government organizations after retiring	Very few (1); less (2); general (3); more (4); a lot (5)	0.060
			S3 Participation in community/village group activities	Never participate (1); rarely participate (2); participate occasionally (3); regularly participate (4); always participate (5)	0.054
		Financial capital (F)	F1 Annual household income after retiring (10,000 yuan)	F1 < 5 (1); 5 ≤ F1 < 10 (2); 10 ≤ F1 < 20 (3); 20 ≤ F1 < 30 (4); F1 ≥ 30 (5)	0.109
			F2 Financial Support (the kind of insurance)	F2 = 0(1); F2 = 1(3); F2 = 2(5)	0.074
		Human capital (H)	H1 Education level	Below primary school (1); primary (2); junior high school (3); high school (4); above high school (5)	0.091
			H2 Number of labor force in households	H2 = 0(1); 1 ≤ H2 ≤ 2(2); 3 ≤ H2 ≤ 4(3); 5 ≤ H2 ≤ 6(4); H2 ≥ 7(5)	0.032
			H3 Health status	Frequent illness (1); occasional illness (2); rare illness (3); relatively healthy (4); very healthy (5)	0.057

3.2.2 Measurement and calibration

In the framework of fuzzy-set qualitative comparative analysis (fsQCA), each condition and outcome is denoted by a unique set, within which each case is endowed with membership scores across various sets (Zhang et al., 2019). These membership scores are determined through a process known as calibration (Fiss, 2011). Calibration can be classified into two distinct categories: direct calibration and indirect calibration. Direct calibration entails a structured assignment process that relies on predefined qualitative anchors, which include fully affiliated, completely unaffiliated

and the crossover point (Rihoux and Ragin, 2008). Conversely, indirect calibration involves the classification of cases based on their sample membership levels, with subsequent assignment of varying membership scores to optimize the analysis (Fiss, 2011; He et al., 2022; Feng et al., 2024). In accordance with the specific characteristics of variable types, direct calibration is applied to livelihood capital within the buffering ability of condition variables. In contrast, indirect calibration is utilized for outcome variables, such as fishermen’s inclination to adopt ecological farming practices, and condition variables including

self-organization ability, learning ability in relation to subsidy benefits, policy awareness, neighborhood trust, technical training, and information exchange.

3.2.2.1 Outcome variables

The willingness of retired fishermen to adopt ecological farming practices is examined as the outcome. Based on the fishermen's intentions regarding the adoption of ecological farming methods, the results are represented using fuzzy set membership scores: a score of "1" is assigned for "very willing," "0.75" for "relatively willing," "0.5" for "neutral toward adoption," "0.25" for "not considering at this stage," and a score of "0" for "unwilling to adopt."

3.2.2.2 Condition variables

Buffering ability—livelihood capital. The direct calibration method was employed to assess and calibrate the results of the five capitals related to fishermen's livelihoods. The standards used for this process were the 0.95 quantile (complete membership), the 0.5 quantile (threshold point), and the 0.05 quantile (complete non-membership). The procedure is as follows.

First, a livelihood capital index evaluation system was constructed, the evaluation index scores were assigned, and the entropy weight method was used to determine the index weights (Table 3).

- (1) Based on the standardized value R_{ij} (the score assignment of the J -th index of the i fisherman), the proportion of the unit i index value in the J -th index is calculated:

$$P_{ij} = R_{ij} / \sum_{i=1}^n R_{ij} \quad (1)$$

- (2) Calculate the entropy value of the J -th index: e_j

$$e_j = -1 / \ln n \sum_{i=1}^n P_{ij} \ln(P_{ij}) \quad (2)$$

- (3) Calculate the difference coefficient of the J -th index: g_j

$$g_j = 1 - e_j \quad (3)$$

- (4) Calculate the weight of J -th index: w_j

$$w_j = 1 - e_j(g_j) / \sum_{i=1}^m 1 - e_j(g_j) \quad (4)$$

- (5) Calculate the composite score of the i fisherman's livelihood capital: s_i

$$s_i = \sum_{j=1}^m (R_{ij} w_j) \quad (5)$$

The direct calibration method was employed to establish the thresholds for the comprehensive scores of fishermen's livelihood

capital, setting the 95th and 5th percentiles as fully affiliated (5.32) and completely unaffiliated (3.6), respectively. The score corresponding to the 50th percentile was designated as the crossover point (4.45) for calibration purposes. For variables related to self-organization ability, including subsidy benefits, policy awareness, neighborhood trust, as well as technical training and information exchange, an indirect calibration method was utilized for scoring affiliation calibration. In the indirect calibration method, the measurement results are re-evaluated based on qualitative assessments (Rihoux and Ragin, 2008). Depending on the research question and substantial knowledge of data and fundamental theories, fuzzy set membership scores for five-point scale variables are calibrated using the indirect calibration method (Furnari et al., 2020), taking into account differences in data types among various variables and outcomes. Thresholds commonly employed include 0, 0.25, 0.5, 0.75, and 1 (Ragin, 2008). Results are presented in Table 4.

4 Results and discussion

4.1 Necessary Condition Analysis (NCA)

In the Necessary Condition Analysis (NCA) method, a condition is considered necessary for an outcome if the effect size (d) is not <0.1 and the Monte Carlo simulation permutation test indicates that the effect size is significant (Vis and Dul, 2008; Liu and Cheng, 2024). Table 5 presents the results of effect sizes calculated using both CR and CE estimation methods. Overall, none of the six antecedent conditions simultaneously meet both the effect size and significance requirements. Therefore, they are not deemed necessary conditions for fishermen's willingness to adopt ecological farming practices.

The "bottleneck level" refers to a specific threshold within which certain values (%) must be satisfied by antecedent conditions in order to achieve a particular level of overall observed outcomes (Du et al., 2020; Luo and Song, 2025). Table 6 further reports bottleneck level (%) analysis of NCA method. The study specifies the percentage of livelihood resilience required to achieve the willingness of retired fishermen to adopt ecological farming practices. For instance, to reach 90% of fishermen's willingness to adopt ecological farming practices within the observation range, it requires a livelihood capital level of 3.0%, technical training at 6.1%, and information exchange at 7.2%. The other three antecedent conditions do not exhibit any bottleneck levels.

4.2 fsQCA necessary condition analysis

Fuzzy set qualitative comparative analysis (fsQCA) method is employed to examine whether individual condition variables, including their logical negations, constitute necessary conditions for the willingness of retired fishermen to adopt ecological farming practices (Mendel and Korjani, 2018). The degree of consistency in fuzzy sets is selected as the measurement criterion for necessity, with the calculation formula presented as follows:

$$\text{Consistency}(Xi \leq Yi) = \sum [\min(Xi, Yi)] / \sum (Xi) \quad (6)$$

TABLE 4 Calibration of conditional variable data.

Condition variables		Indicator meaning	Calibration results
Buffering ability	Livelihood capital	Livelihood capital composite score	Fully affiliation (5.32); crossover point (4.45); completely unaffiliated (3.6)
Self-organization ability	Subsidy benefits	"Have you received the compensation for the vessel network certificate, transitional living allowances, pension and medical insurance subsidies and agricultural production (ecological farming) subsidies provided by the government?"	"All" (1); "three kinds" (0.75); "two kinds" (0.5); "one kind" (0.25); "Neither" (0)
	Policy awareness	"How concerned are you about ecological compensation policies and agricultural production policies adopted by the government?"	"Very concerned" (1); "somewhat concerned" (0.75); "fairly informed" (0.5); "occasionally attentive" (0.25); "never attentive" (0)
	Neighborhood trust	"Will other retired fishermen in the fishing village engaging in ecological farming have a neighborhood effect on your livelihood choices?"	"Very impactful" (1); "comparative impact" (0.75); "general" (0.5); "not much impact" (0.25); "not impact" (0)
Learning ability	Technical training	"How often do you participate in government-organized training on production techniques related to ecological farming?"	"Always participate" (1); "frequently participate" (0.75); "occasionally participate" (0.5); "rarely involved" (0.25); "Never participate" (0)
	Information exchange	"How often do you exchange information with others, such as ecological farming technology and the price of agricultural products?"	"Always Communicate" (1); "Frequently Communicate" (0.75); "Occasionally Communicate" (0.5); "Rarely Communicate" (0.25); "Never Communicate" (0)

TABLE 5 Retired fishermen’s ecological farming willingness-analysis of necessary conditions for NCA method.

Conditions	Methods	Effect size (d)	P-value	Precision	Upper limit area (ceiling zone)	Range (scope)
Livelihood capital	CR	0.010	0.039	99.30%	0.009	0.92
	CE	0.016	0.014	100%	0.015	0.92
Subsidy benefits	CR	0.000	1.000	100%	0.000	0.89
	CE	0.000	1.000	100%	0.000	0.89
Policy awareness	CR	0.000	1.000	100%	0.000	0.85
	CE	0.000	1.000	100%	0.000	0.85
Neighborhood trust	CR	0.000	1.000	100%	0.000	0.85
	CE	0.000	1.000	100%	0.000	0.85
Technical training	CR	0.003	0.050	100%	0.003	0.85
	CE	0.006	0.050	100%	0.005	0.85
Information exchange	CR	0.011	0.245	100%	0.010	0.89
	CE	0.022	0.245	100%	0.020	0.89

0.0 ≤ d < 0.1: "low level", 0.1 ≤ d < 0.3: "medium level", 0.3 ≤ d < 0.5 or d ≥ 0.5: "high level".

In Equation 6, X_i and Y_i are the membership degrees of individual i in combinations X and Y , respectively, and the consistency value ranges from 0 to 1. When the consistency exceeds 0.9, it is deemed that this condition is a necessary condition for the outcome (He et al., 2022; Sun et al., 2024). Table 7 presents the results of calculating the necessary conditions for fishermen’s willingness to adopt ecological farming based on fsQCA 3.0. It can be observed that all conditions exhibit a consistency lower than 0.9, which aligns with the findings from NCA analysis, indicating that there are no necessary conditions influencing fishers’ willingness to adopt ecological farming practices following fishing bans.

4.3 Conditional configuration adequacy analysis

The sufficiency of configurational conditions is the core discussion of the fsQCA method (Mendel and Korjani, 2012). From a set-theoretic perspective, it explores whether the configuration represented by multiple conditions constitutes a subset of the outcome set. When selecting consistency to measure the sufficiency of configurations, it is considered that the level of sufficiency should not be lower than 0.75 (Zhang et al., 2019; Zhu et al., 2022). The sample size determines the assignment of frequency thresholds. For small to medium samples, the frequency threshold is set at 1,

TABLE 6 Bottleneck level (%) analysis of NCA method.

Fishermen's willingness to adopt ecological farming	Livelihood capital	Subsidy benefits	Policy awareness	Neighborhood trust	Technical training	Information exchange
0	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	NN
20	NN	NN	NN	NN	NN	NN
30	NN	NN	NN	NN	NN	NN
40	NN	NN	NN	NN	NN	NN
50	0.0	NN	NN	NN	NN	NN
60	0.8	NN	NN	NN	NN	1.4
70	1.5	NN	NN	NN	NN	3.6
80	2.3	NN	NN	NN	5.4	NN
90	3.0	NN	NN	NN	6.1	7.2
100	3.8	NN	NN	NN	8.3	9.8

Upper limit regression analysis CR; NN, unnecessary.

TABLE 7 Analysis of necessary conditions for QCA method.

Condition variable	Retired fishermen have strong willingness to adopt ecological farming		Retired fishermen have weak willingness to adopt ecological farming	
	Consistency	Coverage	Consistency	Coverage
Subsistence capital	0.520	0.560	0.628	0.622
~Livelihood capital	0.649	0.655	0.556	0.516
Subsidy benefits	0.603	0.621	0.601	0.569
~Subsidy benefits	0.582	0.613	0.599	0.581
Policy awareness	0.693	0.605	0.732	0.587
~Policy awareness	0.527	0.681	0.507	0.603
Neighborhood trust	0.553	0.581	0.624	0.603
~Neighborhood trust	0.622	0.643	0.566	0.538
Technical training	0.459	0.541	0.588	0.637
~Technical training	0.692	0.646	0.576	0.495
Information exchange	0.851	0.553	0.886	0.530
~Information exchange	0.277	0.725	0.253	0.609

~Indicates non-logical.

while for large samples, it should exceed 1 (Tao et al., 2021). Taking into account both sample size and case arrangement in the truth table, we ultimately selected a consistency threshold of 0.80 and a frequency threshold of 2.

The outcomes of the fuzzy-set qualitative comparative analysis (fsQCA) present three solution types, each with its own level of complexity: complex solutions, parsimonious solutions, and intermediate solutions (Du et al., 2020). Typically, contemporary research tends to report on intermediate solutions, while delineating core conditions from peripheral conditions in tandem with parsimonious solutions. Conditions that manifest in both the parsimonious and intermediate solutions are designated as core conditions. Conversely, those that are exclusive to the intermediate solution are categorized as peripheral conditions (Jiang et al., 2021). The configuration analysis results regarding fishermen's willingness to adopt ecological farming are presented in Table 8.

4.3.1 Configuration (path) with strong willingness of fishermen to adopt ecological farming

Table 8 delineates three distinct pathways that influence fishermen's pronounced inclination to embrace ecological farming practices. The levels of consistency for both individual and collective solutions surpass 0.75, with the collective solution exhibiting a consistency level of 0.771. This suggests that 77.1% of retired fishermen express a strong inclination to engage in ecological farming subsequent to their retirement from fishing. The coverage of the collective solution is 0.623, indicating that these three conditional configurations account for 62.3% of cases characterized by a strong inclination to adopt ecological farming among fishermen. These configurations can be deemed as sufficient combinations of conditions that cultivate a robust inclination among fishermen toward ecological farming practices. Upon further examination, these conditional configurations reveal

TABLE 8 Capacity configuration of retired fishermen's willingness to adopt ecological farming.

Conditional configuration	Fishermen have strong willingness to adopt ecological farming			Fishermen have weak willingness to adopt ecological farming		
	Self-organization dominant	Self-organization—learning driven	Buffering—learning driven	Learning inhibition	Self-organization—learning inhibition	Buffering—self-organization inhibition
Conditional configuration	Configuration 1	Configuration 2	Configuration 3	Configuration 4	Configuration 5	Configuration 6
Livelihood capital	⊗	⊗	●	●		⊗
Subsidy benefits	●	●	⊗		⊗	⊗
Policy awareness	●		⊗	⊗	●	
Neighborhood trust		●	⊗			⊗
Technical training	⊗	⊗	●	⊗	⊗	●
Information exchange	⊗	●	●	⊗		●
Consistency	0.785	0.803	0.792	0.816	0.798	0.837
Raw coverage	0.284	0.252	0.309	0.190	0.167	0.231
Unique coverage	0.077	0.116	0.140	0.076	0.080	0.152
Consistency of solution	0.771			0.793		
The coverage of the solution	0.623			0.656		

● or ● if the condition exists, ⊗ or ⊗ if the condition does not exist; ● or ⊗ is the core condition, and ● or ⊗ is the edge condition. Blank indicates that the condition can be present or absent.

distinct pathways influenced by buffering, self-organization, and learning that affect fishermen's inclination to adopt ecological farming.

(1) Self-organization dominant. Configuration 1 elucidates the pivotal role played by subsidy benefits and policy awareness. In the context of fishermen's inclination to embrace ecological farming practices, heightened policy awareness and a perception of governmental subsidies can surmount the constraints imposed by buffering and learning conditions. The instances elucidated by configuration 1 predominantly cluster in counties situated along the lower reaches of the Yangtze River and in comparatively developed eastern counties. These areas extend subsidies to retired fishermen in accordance with criteria applicable to land-lost farmers (Gao et al., 2025), while also committing substantial resources to the promotion of agricultural technology and policy advocacy, thereby augmenting fishermen's comprehension of ecological farming. Jiangsu Province, as a representative region, boasts a substantial cohort of retired fishermen and significant retirement obligations. Initially, during the inception of fishing bans, fishermen generally endorsed the prohibition of fishing in key areas of the Yangtze River but were deficient in requisite knowledge pertaining to agricultural production

support policies and ecological farming assistance programs. Local governments have augmented fishermen's awareness of ecological farming through promotional endeavors centered on reward-and-subsidy policies. The consistency for this pathway configuration is 0.785, with unique coverage at 0.077 and raw coverage at 0.284. This signifies that this pathway can account for ~28.4% of instances where fishermen exhibit a robust willingness. Moreover, ~7.7% of instances wherein fishermen are inclined to engage in ecological farming can exclusively be attributed to this pathway.

(2) Self-organization-learning driven. In Configuration 2, the pivotal role is played by neighborhood trust, with subsidies benefits and information exchange serving as supplementary factors. The cases elucidated by this conditional configuration predominantly concentrate on remote fishing villages situated in the western regions of China and the upper reaches of the Yangtze River. These villages are frequently situated in geographically isolated areas, characterized by relatively weak foundations for aquaculture production, coupled with limited government support coverage (Xu et al., 2024), which somewhat impedes the dissemination of ecological farming models. Neighborly interaction and shared communication have become essential conduits for fishermen to acquire information. Thus, their interactive networks constitute

critical social capital for the survival and development of mobile populations within these villages. Fishermen endowed with robust social trust may be influenced by their peers to enhance their willingness to adopt ecological farming, thereby generating a neighbor effect. For example, fishermen from County F in Sichuan Province mentioned that after ceasing fishing activities, they learned from local fishermen about job opportunities at an integrated rice-fish farming demonstration base where they could earn wages and receive industry dividends at year-end. The concept of “medium rice + regenerated rice” can be succinctly described as “one crop, two harvests.” Following the harvesting of the main crop of rice by the end of July each year, the dormant axillary buds on the stubble can regenerate under specific conditions. Approximately 2 months later, these buds will develop into panicles, facilitating an additional harvest. The former refers to medium rice, while the latter is referred to as regenerated rice. Owing to the capacity of “medium rice + regenerated rice” to enhance the cropping index and stabilize the overall yield of rice, this area promotes a “medium rice + regenerated rice + fish” green ecological farming model that aids fishermen in transitioning toward environmentally sustainable practices while achieving collective prosperity. In H District of Chongqing City, initiatives promoting simultaneous rice-shrimp cultivation have been implemented to augment fishermen’s incomes. Capitalizing on high-standard farmland construction opportunities, this district has actively developed 23,000 acres dedicated to rice-shrimp farming involving 46 major operators. After retiring from fishing activities, local fishermen can join village cooperatives to access relevant information and assist during peak production periods. The consistency score for this driving path configuration is 0.803 with an original coverage rate of 0.252; it accounts for ~25.2% of cases demonstrating a strong willingness among fishermen to adopt ecological farming.

- (3) Buffering-learning driven. In Configuration 3, the pivotal roles are occupied by livelihood capital and technical training, with information exchange acting as a complementary function. In areas where fishermen have a higher level of livelihood capital, even with low policy awareness and diminished trust in external entities and government subsidies, supportive learning conditions can still motivate fishermen to actively respond to external disruptions and increase their inclination to seek employment. The consistency of this configuration is 0.792, with an original coverage rate of 0.309. Examples that can be elucidated by Configuration 3 encompass the three provinces situated along the middle reaches of the Yangtze River: Hunan, Jiangxi, and Anhui. Initially, this region possesses significant natural advantages. The middle reaches of the Yangtze River constitute a primary production base for staple grains in China, endowed with abundant water resources and favorable climatic conditions for agricultural production, owing to concurrent rainfall and heat (Gao and Sun, 2023). The proportion of individuals transitioning into other forms of employment who were previously engaged in farming exceeds 60%. Secondly, government initiatives aimed at augmenting fishermen’s capital endowments ensure their productive

activities are protected. This includes optimizing service systems to enhance both material and financial capital for fishermen (Yu et al., 2024)—such as acquiring agricultural machinery, upgrading basic irrigation infrastructure in fishing villages, providing direct financial subsidies, and offering credit support. Moreover, efforts are made to enhance technical training for fishermen to elevate human capital levels through the dissemination of knowledge on production operations and refined management practices. Community organizations also play a vital role by establishing cooperatives or mutual aid groups that connect social capital with ecological farming interests among fishermen (Gao and Liu, 2022). This reduces information costs while increasing organizational capacity within these communities. For example, the “Encouraging Ecological Practices” initiative necessitates a combination of rich natural assets alongside robust infrastructure and proficient collaborative techniques. Given that retired fishermen often encounter challenges such as lower educational attainment or slower skill acquisition rates post-retirement from fishing activities, active participation in ecological cultivation technology training becomes crucial for enhancing operational skills. As a representative case study: County N in Hunan invited experts to deliver lectures on aquaculture knowledge while exploring digital empowerment strategies using new media platforms like big data to facilitate learning among local fishermen (Gao and Sun, 2023). In B Township of Anhui Province, training methods integrated indoor technical instruction with on-site guidance. Experts initially provided explanations on livestock and poultry farming, disease prevention, and the techniques for mugwort cultivation (Liu et al., 2024). They distributed technical guidance manuals and promoted policies to support fishermen. Subsequently, they led the fishermen in hands-on practice in the fields. Meanwhile, Y County’s government in Jiangxi has integrated retired fishermen into community management frameworks while coordinating education health care services alongside housing security measures which collectively enhance their livelihood capitals. On the other hand, fishermen have proactively engaged in learning courses on eel farming and Ganpo mushroom cultivation (Ying, 2024), thereby enhancing their willingness to adopt ecological practices in agriculture and aquaculture.

4.3.2 Configuration (path) of fishermen’s weak willingness to adopt ecological farming

As depicted in Table 8, three distinct pathways culminate in the observed outcomes. Each pathway, along with the aggregate consistency of the solutions, surpasses 0.75, signifying that the antecedent variables possess a robust explanatory capability for the results. Furthermore, the aggregate coverage rate stands at 0.656, indicating that these configurational pathways elucidate 65.6% of the cases. Drawing upon the core conditions encapsulated within these pathways, the three identified types influencing fishermen’s diminished inclination to embrace ecological farming are: learning inhibition (Configuration 4), self-organization—learning inhibition

(Configuration 5), and buffering—self-organization inhibition (Configuration 6).

An examination of these three categories reveals that buffering ability, self-organizational ability, and learning ability are pivotal constraints that influence retired fishermen’s inclination to participate in ecological farming. Initially, a substantial base of livelihood capital is essential for augmenting the propensity for ecological farming adoption. The absence of adequate human, physical, social, financial, and natural capital resources among fishermen significantly heightens their vulnerability (He and Chen, 2022). This reduction in resources undermines their confidence in pursuing ecological farming for livelihood advantages. Subsequently, self-organizational ability is pivotal in establishing subjective intentions toward ecological farming among fishermen. When self-organizational abilities are diminished, reliance on a diverse array of government incentive policies may be necessary to stimulate fishermen’s willingness to adopt ecological farming. Concurrently, within the context of interactions involving institutional policies and social networks, should fishermen find it challenging to enhance their motivation for technology adoption through spontaneous or collective actions, their self-organizational abilities will be insufficient in reinforcing their inclination toward ecological farming. Ultimately, learning ability is crucial for fostering farmers’ willingness to adopt eco-friendly farming methodologies. It also serves as a prerequisite for engaging in such agricultural models. Should fishermen demonstrate a lack of initiative in learning or possess inadequate information literacy skills, it becomes arduous for them to cultivate intrinsic motivations toward adopting ecological farming practices.

4.3.3 Potential substitution relationship between conditions

The comparative analysis of condition configurations 1–3 allows for the further identification of potential substitutive relationships among buffering, self-organization, and learning abilities. Firstly, by comparing condition configurations 1 and 2, it is observed that in regions where fishermen have a higher sense of entitlement to ecological farming subsidies, the level of policy awareness among fishermen (self-organization) can substitute for the combination of neighborly trust (self-organization) and information exchange (learning), as illustrated in Figure 2. Secondly, the comparison between condition configurations 2 and 3 indicates that in areas with strong information exchange capabilities and high levels of information literacy among fishermen, the combination of subsidy benefits perceived by fishermen (self-organization) and neighborly trust (self-organization) can serve as a substitute for the combination of livelihood capital accumulation (buffering) and proactive technical training engagement (learning), thereby enhancing fishermen’s willingness to engage in ecological farming, as shown in Figure 3.

The potential substitutive relationship among buffering, self-organization, and learning conditions indicates that under specific circumstances, the capacity for self-organization can exert effects typically associated with the combination of the other two abilities, as illustrated in Figures 2, 3. The interdependence and complementarity of three conditions—subsidy benefits, policy awareness, and neighborhood trust—generate a certain synergistic effect on explaining outcomes.

Initially, fishermen procure technical and policy-related information via governmental promotional initiatives and

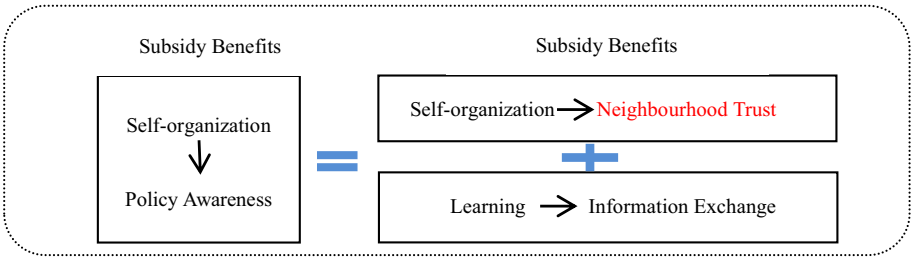


FIGURE 2 Substitution relationship between self-organization and “Self-organization + learning”.

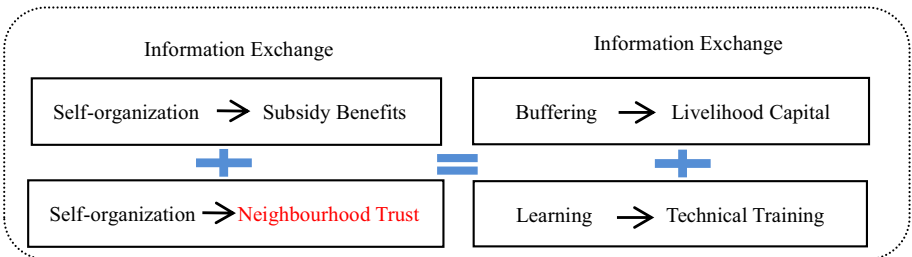


FIGURE 3 Substitution relationship between self-organization and “buffering + learning”.

community engagement efforts (Shang and Yang, 2021), thereby establishing their foundational comprehension of production methodologies and subsidy frameworks. This comprehension is subsequently molded by their assessment of the perceived advantages conferred by subsidies, coupled with the insights imparted by friends or kinfolk concerning the risks and rewards inherent in these models. As a result, they evaluate the applicability and sustainability of ecological farming technologies to ascertain their inclination toward the adoption of such practices.

Figure 2 elucidates that heightened awareness of agricultural policies is positively associated with increased governmental dedication to the enactment of these policies. Consequently, this heightened awareness leads to augmented satisfaction among farmers with the policies and a greater inclination to adopt ecological farming technologies. In contrast to the unilateral decision-making process that is often based on individual perceptions among fishermen, the establishment of trust between neighboring fishers significantly bolsters confidence in the adoption of ecological farming methodologies. A significant level of information transparency and trust among fishermen can, to some extent, reduce risk perceptions and foster consensus in terms of livelihood choices (Liu et al., 2019b). Figure 3 delineates that fishermen engage in ecological farming through two distinct approaches: “social partnership” or “independent contracting.” The “social partnership” model necessitates the active involvement of governments in various aspects such as policy support, financial resources, technology transfer, etc., to encourage selected fishermen to spearhead efforts in ecological farming. Those who achieve higher yields disseminate their experiences to others, thereby expanding the demonstration effects and facilitating the establishment of “catch-to-culture” production bases while exploring partnerships that involve “base + retired fishers.” Conversely, the “independent contracting” approach is employed when fishermen leverage a combination of buffering and learning abilities to compensate for insufficient self-organizational capacity required to enhance interest in ecological farming practices. Sufficient livelihood capital provides an objective foundation for engaging in ecological farming and partially addresses any gaps resulting from weak perceptions regarding subsidy benefits. Additionally, acquiring knowledge pertaining to pond disinfection techniques, seedling selection, feed management, and disease prevention strategies effectively enhances farmers’ comprehension of eco-friendly practices while mitigating constraints imposed by inadequate neighborly influence. Fishermen independently utilize natural water surface contracts alongside land cultivation techniques for rice-shrimp/rice-fish entrepreneurial ventures. Both pathways ultimately converge to increase farmers’ willingness to adopt sustainable practices.

4.4 Fishermen’s willingness by generation and regional economic contexts

Yangtze River retired fishermen typically exhibit characteristics of diminished livelihood capital, including “advanced age, limited educational attainment, and absence of land or alternative

skills.” Having traditionally depended on aquatic resources, these individuals often possess survival skills that are confined to their fishing expertise (Sun et al., 2024). To mitigate the risks associated with their livelihoods, they tend to seek employment primarily in the sectors of agriculture, forestry, animal husbandry, and fishery (Xie et al., 2022). Ecological farming not only aids in poverty alleviation and wealth creation for these fishermen but also represents a sustainable and circular low-carbon production model that can yield benefits for both ecological conservation and economic development. Consequently, local governments throughout China are encouraging fishermen to explore new avenues toward higher-quality employment while simultaneously enhancing ecological benefits. With supportive conditions, there is a concerted effort to promote the development of integrated ecological farming systems within these communities.

To further investigate the impact of livelihood resilience on the willingness of retired fishermen to adopt ecological farming practices, this study examines variations among different groups of fishermen characterized by distinct attributes and regions with varying levels of economic development. Specifically, a heterogeneity analysis is conducted from two perspectives: generational differences and regional economic development levels. Firstly, in accordance with generational difference theory, fishermen at various age stages exhibit differences in values, knowledge skills, and physical capabilities. These differences may influence how livelihood resilience affects the willingness of retired fishermen to adopt ecological farming practices. Therefore, based on the age differences among household and actual samples of fishermen, those born before 1980 with an education level up to junior high school are categorized as the “older generation” group; all other samples are classified as the “younger generation” group for our analysis. Secondly, regions with varying levels of economic development display differences in living standards and labor market activity. Such differences can also affect how livelihood resilience influences retired fishermen’s willingness to adopt ecological farming practices. Consequently, based on regional economic development disparities—specifically whether local per capita GDP exceeds that year’s average per capita GDP in China—we classify samples above this mean into a “high economic development region” group and those below it into a “low economic development region” group for our analysis. Additionally, considering that sample sizes after grouping may be relatively small, which could potentially impact the accuracy of parameter estimates, this study employs Bootstrap methods for repeated sampling alongside OLS estimation techniques for regression analysis. The control variables in this study encompass individual, family, and regional factors. The individual control variables include age and gender, while the family control variables consist of the proportion of labor force participation and the dependency ratio. The regional control variable pertains to the level of economic development (see Tables 9, 10).

Table 9 reports the regression results regarding the impact of livelihood resilience on the ecological farming willingness of retired fishermen, categorized as either new-generation or old-generation groups. It is evident that, in contrast to the new-generation fishermen who are not significantly affected, livelihood resilience has a significant positive effect on the willingness of

TABLE 9 Regression results on the impact of livelihood resilience on ecological farming willingness among retired fishermen from the perspective of intergenerational differences.

Variables	Ecological farming willingness	
	The groups of new-generation retired fishermen	The groups of older-generation retired fishermen
Livelihood resilience	0.0514	0.5237***
	(0.0403)	(0.0315)
Control variables	Controlled	Controlled
County and district level fixed effects	Controlled	Controlled
Observation index	102	295

(1) *** indicates a significance level of 1%. (2) The values in parentheses represent robust standard errors.

TABLE 10 Grouped regression results of regional economic development disparities.

Variables	Regions with high economic development levels	
	Regions with high economic development levels	Regions with low economic development levels
Livelihood resilience	0.0982	0.3527***
	(0.0409)	(0.0326)
Control variables	Controlled	Controlled
County and district level fixed effects	Controlled	Controlled
Observation index	118	279

(1) *** indicates a significance level of 1%. (2) The values in parentheses represent robust standard errors.

old-generation fishermen to engage in ecological farming at a 1% statistical level. This suggests that livelihood resilience primarily influences the adoption intentions among retired fishermen belonging to the older generation. A possible explanation for this phenomenon is that compared to their younger counterparts, older fishermen often face limitations such as inadequate knowledge and skills, as well as lower cultural literacy levels. Additionally, they tend to have a stronger attachment to their local communities. Under these dual constraints—capability and emotional ties—older fishermen encounter substantial challenges in accessing development opportunities. Furthermore, factors such as declining physical strength and health issues may hinder their ability to participate in agricultural labor production. Therefore, an enhancement in livelihood resilience can provide them with greater confidence in employment opportunities.

Table 10 reports the regression results regarding the impact of livelihood resilience on the ecological farming willingness of retired fishermen in regions with high and low economic development levels. It is evident that, unlike the unaffected group in high economic development areas, livelihood resilience significantly influences the ecological farming willingness of retired fishermen in low economic development areas at a 1% statistical level. This suggests that livelihood resilience has a more pronounced effect on this demographic within lower economic contexts. A possible

explanation for this phenomenon is that in regions with higher economic development, retired fishermen benefit from improved living standards and an active labor market, which enhances their capacity to adapt. Conversely, in areas with lower economic development levels, even if fishermen possess a strong desire for growth, they often find themselves trapped in relative poverty due to a lack of adaptive policies, developmental opportunities, and geographical constraints. The government's implementation of diversified ecological compensation measures bolsters their livelihood resilience and addresses these fishermen's developmental needs while facilitating better opportunities for re-employment.

5 Concluding remarks

5.1 Conclusions

This investigation examines the inclination of retired fishermen from representative provinces along the Yangtze River to engage in ecological farming subsequent to the imposition of a fishing moratorium, utilizing fsQCA for the analysis of conditional configurations. It delves into the interplay of six conditional variables—namely, livelihood capital, subsidy benefits, policy awareness, neighborhood trust, technical training, and information exchange—on the willingness of these fishermen to embrace an “ecological farming” lifestyle. The study uncovers the central conditions and intricate mechanisms that shape fishermen's intentions to adopt ecological farming. The research culminates in the following conclusions:

- The necessity analysis conducted through NCA and fsQCA demonstrates that buffering, self-organization, and learning abilities, in isolation, are insufficient to yield explanatory outcomes. This implies that individual conditions do not restrict fishermen's inclination toward “ecological farming”. A pronounced propensity for ecological farming is fostered through three distinct avenues: a self-organization-dominant pathway, a self-organization and learning-driven pathway, and a buffering and learning-driven pathway. The inclination of fishermen toward ecological farming emerges as a consequence of the combined influence of multiple conditions, where various variables interact to forge paths toward adoption, with different approaches converging toward analogous outcomes. In particular scenarios, an increased focus by fishermen on ecological farming policies positively correlates with the extent to which subsidy resources benefit them. The synergy of these two factors can surmount the constraints imposed by buffering and learning elements, thereby augmenting fishermen's inclination to adopt such practices. When self-organizational ability is constrained, enhancements in fishermen's livelihood capital, encouragement to actively participate in government-organized training programs, and reinforcement of information communication can also collaboratively augment their inclination.
- The relationship between the robust inclination of fishermen to adopt ecological farming and the feeble inclination exhibits causal asymmetry. There are three categories of driving factors

that contribute to the tepid adoption inclination among fishermen regarding ecological farming: inhibition of learning ability, inhibition of self-organization and learning ability, and inhibition of buffering and self-organization ability. A comparison of these three driving types reveals that buffering ability, self-organization ability, and learning ability are all critical constraints on the inclination of retired fishermen to engage in ecological farming.

- c) The potential substitutive relationship among buffering, self-organization, and learning conditions indicates that the three conditions under self-organizational ability play a more significant role. However, under specific circumstances, self-organizational ability can equivalently substitute for the conditions of the other two abilities in a manner that enhances fishermen's inclination to adopt through a "different paths leading to the same destination" approach.
- d) As rational economic agents, fishermen are direct stakeholders in policies concerning fishing bans. When ecological farming presents both environmental and economic benefits, fishermen may contemplate transitioning toward ecological farming to maximize their gains. Consequently, the government underscores the development of new pathways for ecological farming. In various contexts, the impact of livelihood resilience on the inclination of fishermen in the Yangtze River Basin of China to adopt ecological farming primarily concentrates on two groups: the older generation of fishermen and those from regions with lower economic development levels.

5.2 Practical implications

The "visible hand" service function should employ a range of communication channels, including informational brochures, flyers, and television broadcasts, to enhance the promotion of aquaculture policies. This will improve fishermen's foundational comprehension of these initiatives. Concurrently, it is imperative to concentrate on elucidating critical elements that are of particular concern to fishermen, such as subsidy ratios and methodologies. Moreover, provision of consumption credit loans and interest subsidies for those actively engaging in ecological farming is essential. This ensures that fishermen can participate in these activities with confidence and security.

Furthermore, the potential interplay among buffering, self-organization, and learning underscores the indispensable nature of these three abilities for the willingness of fishermen. It is not only necessary to augment the livelihood capital of fishermen but also to fully utilize the synergistic effects of their existing capital endowments. Incentive measures should be implemented to guide fishermen in achieving a rational allocation of capital factors pertinent to their willingness to engage in ecological farming. It is also crucial to refine subsidy programs for aquaculture by considering a blend of one-time and annual subsidies, as well as direct and indirect support during implementation. This approach will enhance the perceived benefits of policies while focusing on incentive policies that ensure momentum for ecological farming. Fishermen must overcome passive attitudes such as "going through

the motions" or reliance on others. They must shift their mindset and actively engage with various government policies and news releases, thereby enhancing their awareness level. Additionally, they should proactively expand their local social networks and community interactions to strengthen neighborhood effects. Moreover, training content should be innovatively presented in an accessible manner while being flexible regarding timing, location, and format. This will increase fishermen's interest in learning. Strengthening information network infrastructure is vital for broadening access opportunities related to ecological farming. Fishermen can quickly acquire comprehensive information by actively participating in village-level exchange meetings and listening to experience-sharing sessions from demonstration households engaged in sustainable practices.

Lastly, the governments of provinces along the Yangtze River should formulate supportive policies for ecological farming based on their specific circumstances and the reasonable demands of local fishermen, adopting a "localized" approach. Moderately enhancing the government's ecological compensation policy can improve the precision of promoting the willingness of retired fishermen in the Yangtze River Basin to adopt ecological farming practices. In economically underdeveloped areas that were previously impoverished, it is essential to focus on developing green ecological industries based on local natural resource endowments, thereby driving employment and skills training for the local population. Regarding subsidies, it may adopt an annual subsidy approach to enhance perceived benefits while appropriately balancing minimum standards with variable coefficients. This strategy aims to reduce psychological disparities among fishermen and mitigate risks associated with comparison pressures. Additionally, under an information-sharing framework, efforts should be made to incorporate high-quality resources from the high-developed regions into local services, maximizing synergistic support effects. Furthermore, increasing the supply of diversified ecological compensation for older generations of retired fishermen will facilitate improvements in their development capabilities and income potential, as well as enhance the quality of life in their communities. This approach aims to strengthen the effectiveness of poverty alleviation efforts among local fishermen.

5.3 Limitations and future prospects

This study is subject to several limitations. Firstly, subsequent research should aim to expand the sample size, select additional regions to validate the outcomes, and conduct comparisons of the levels of livelihood resilience and their influencing factors across diverse regions. Secondly, the current study has confined its examination of livelihood resilience to three dimensions: buffering ability, self-organizational ability, and learning ability. Future research endeavors may encompass a broader spectrum of aspects, such as multi-source interference, ecological impacts, and policy alterations. Furthermore, the assessment of ecological farming willingness is inherently subjective, and it is plausible that fishermen with varying livelihood strategies and life circumstances may hold disparate perceptions and

exhibit divergent behaviors when evaluating identical subjects. Consequently, it is imperative to assess and substantiate the correlation between willingness and livelihood resilience within various cohorts of retired fishermen and at distinct junctures of their livelihood progression.

Data availability statement

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

Ethics statement

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

Author contributions

XW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft. JZ: Investigation, Writing – review & editing. YY: Funding acquisition, Supervision, Writing – review & editing. TC: Funding acquisition, Supervision, Writing – review & editing.

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