Designing Rural Policies for Sustainable Innovations through Participatory Governance: A Multi-Stakeholder Collaborative Mechanism and Its Efficacy Study

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***Abstract*—Against the backdrop of global climate change and ongoing rural revitalization efforts, sustainable innovation in rural areas has become a key pathway toward modernizing agriculture. However, traditional top-down policy approaches often fail to account for local differences and the real needs of stakeholders on the ground. This mismatch can lead to difficulties in implementation, low adoption of innovative practices, and poor coordination among the various actors involved. Most existing studies tend to focus either on analyzing policy documents or on the responses of individual stakeholder groups. Far less attention has been given to how collaboration among multiple stakeholders can be effectively built into the early stages of policy design. To address this gap, this study draws on the concept of participatory governance and proposes a hybrid decision-support framework that combines dynamic SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis with the Analytic Hierarchy Process (AHP). The goal is to better support the design of sustainable innovation policies in rural contexts. The framework is applied through a series of multi-stakeholder workshops conducted in a representative agricultural county in East China. Participants included government officials, farmers, agribusiness representatives, researchers, and NGOs. A total of 150 valid responses were collected and analyzed to identify key policy priorities. The findings reveal that "insufficient financial support" and "increasing market competition" are seen as the most critical external challenges. At the same time, internal issues—particularly those related to service capacity and training — emerge as major areas requiring policy attention. Building on these results, the study also offers practical insights into participatory policy design, highlighting how involving diverse stakeholders can improve the relevance, responsiveness, and feasibility of policies. Overall, the research extends the application of participatory governance in rural development and provides policymakers with a practical, adaptable, bottom-up framework for supporting sustainable transitions in rural areas, especially in developing countries.**

Keywords—Participatory Governance, Sustainable Innovation, Multi-Stakeholder Collaboration, SWOT-AHP Model, Rural Revitalization, Policy Designc

I. INTRODUCTION

Against the combined pressures of globalization and climate change, rural areas are increasingly confronted with challenges such as environmental degradation, population decline, and weakening industrial competitiveness [1]. In response, promoting sustainable innovation — ranging from green agricultural technologies and circular farming models to new forms of agricultural management — has become a widely recognized strategy among governments and international organizations [2]. In China, as the "Rural Revitalization" strategy continues to advance, designing effective policies to support rural sustainable innovation is not only essential for agricultural modernization but also closely tied to the livelihoods of hundreds of millions of farmers and the country's broader ecological security [3].

That said, traditional approaches to rural policy design have largely followed a top-down model. While this approach can be efficient in terms of resource allocation and implementation, it often struggles in practice due to its limited sensitivity to local differences. In many cases, it fails to fully incorporate the perspectives and needs of grassroots stakeholders—such as smallholder farmers, local businesses, and cooperatives [4]. This disconnect can lead to policies that do not align well with actual conditions, resulting in low adoption rates of innovative practices and weak coordination, or even conflict, among stakeholders [5].

In recent years, participatory governance has emerged as an alternative approach that emphasizes collaboration, shared decision-making, and bottom-up input. It has shown promising results in areas like urban planning, public health, and environmental management [6]. In rural development, initiatives such as the European Union's Community-Led Local Development (CLLD) and Agricultural Knowledge and Innovation Systems (AKIS) highlight the benefits of involving stakeholders more directly in the policy process [7]. However, research on participatory governance in the context of rural China still has notable gaps. Much of the existing work remains either conceptual or focused on evaluating policies after implementation, with limited attention to how multi-stakeholder collaboration can be

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effectively integrated into the early stages of policy design. Additionally, there is a lack of studies that combine qualitative and quantitative methods to systematically compare participatory approaches with traditional models [8].

To address these gaps, this study explores how participatory governance can inform the design of policies for rural sustainable innovation. It focuses on two key questions: how to construct a policy design framework that meaningfully integrates the perspectives of multiple stakeholders, and which factors should be prioritized in local policy development. To answer these questions, the study introduces a dynamic SWOT-AHP model and applies it through multi-stakeholder workshops conducted in a representative agricultural region in East China. This approach helps identify key influencing factors and generate practice-oriented policy insights [9][10]. The analysis is intentionally scoped to local-level agricultural innovation policies, excluding broader macroeconomic influences to maintain focus and clarity [11].

The remainder of the paper is structured as follows: Section 2 reviews the relevant literature on participatory governance and rural innovation [12]; Section 3 outlines the research methodology, including the model framework and Group B design [13]; Section 4 presents the data sources and preprocessing steps [14]; Section 5 reports the quantitative findings and comparative results for Group B [15]; Section 6 provides a detailed discussion and interpretation of the results [16]; and Section 7 concludes the study and suggests directions for future research [17].

II. Literature Review

A. Rural Sustainable Innovation and Policy Dilemmas

Sustainable innovation in rural areas spans a wide range of practices, from precision agriculture and organic farming to biomass energy utilization. At its core, it aims to achieve a balance between economic development and environmental protection [18]. However, the spread of such innovations is far from automatic. According to Rogers' Diffusion of Innovations theory, factors such as technological complexity, perceived benefits, and the structure of social networks play a crucial role in determining adoption rates [19].

In China's rural context, several structural barriers make this process even more difficult. These include relatively homogeneous social networks, strong risk aversion among smallholder farmers, and limited access to information [20]. To address these issues, governments have introduced a variety of subsidies and policy incentives [21]. Yet, many scholars argue that these efforts often fall into a "one-size-fits-all" approach, overlooking local diversity [22]. For example, Sun et al. found that rural development planning without meaningful local participation can lead to conflicts over land rights and weaken development momentum [23]. Other studies also highlight that insufficient public participation remains a key obstacle to the effective implementation of rural revitalization policies in China [24]. Together, these challenges point to the need for rethinking the underlying logic of policy design [25].

B. Participatory Governance and Multi-Stakeholder Collaboration

Participatory governance emphasizes the direct involvement of citizens and social organizations in public decision-making through institutionalized channels [26]. In the context of environmental management and rural development, this idea has evolved into multi-stakeholder collaboration mechanisms [27]. Research by Pahl-Wostl in water resource management shows that participatory approaches can integrate technical knowledge with stakeholder values, thereby improving both the legitimacy and effectiveness of policies [28].

More recently, studies on Agricultural Knowledge and Innovation Systems (AKIS) have further underscored the importance of collaboration across different actors [29]. Sutherland et al. describe AKIS as an innovation network that connects researchers, extension services, enterprises, and farmers, with its success relying heavily on shared learning and co-creation of knowledge [30]. In China, empirical research has also confirmed the effectiveness of multi-stakeholder governance and revealed the networked nature of rural collaboration [31]. However, much of this work remains at the level of conceptual discussion or mechanism description, with limited development of concrete participatory policy design tools or rigorous empirical testing of their effectiveness [32].

C. Decision-Support Tools: Extending the SWOT-AHP Approach

In strategic analysis, SWOT (Strengths, Weaknesses, Opportunities, Threats) is a widely used tool for assessing internal and external conditions. However, traditional SWOT analysis is often criticized for being overly subjective and lacking a clear way to prioritize factors. To address this limitation, Kurttila et al. introduced the Analytic Hierarchy Process (AHP) into SWOT, creating the hybrid SWOT-AHP method, which enables quantitative weighting and ranking of key factors.

This combined approach has been widely applied in areas such as regional development and agricultural planning. For instance, Zhang et al. used SWOT-AHP to evaluate the potential of leisure agriculture in Henan Province, while Fan et al. applied it to cultural industry development in Shaanxi Province. Cisilino et al. further integrated participatory methods with dynamic SWOT in the context of rural innovation policy design in Italy, demonstrating its effectiveness in incorporating local knowledge into decision-making.

Building on these foundations, this study applies a participatory SWOT-AHP framework to the context of China's rural revitalization. Unlike prior work that often emphasizes resource-intensive validation processes, this study focuses on identifying priority factors, structuring stakeholder input, and generating practical policy insights. In doing so, it contributes new empirical evidence on how participatory approaches can be operationalized in rural policy design and helps bridge the gap between theoretical concepts and real-world application.

III. Methodology

A. Research Strategy and Overall Architecture

This study follows a structured approach summarized as "model construction → participatory decision-making → practice-based assessment." It begins by developing a multi-stakeholder participatory SWOT-AHP model for policy design. Next, local workshops are conducted to bring

together different stakeholder groups, allowing them to identify key influencing factors and discuss policy priorities collaboratively. Finally, the resulting policy framework is interpreted through implementation-oriented observations and feedback from participants. The overall research process is illustrated in Figure 1.

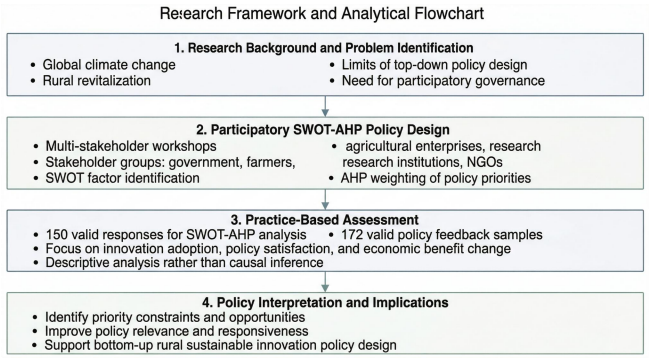

Fig. 1. Research Framework and Analytical Flowchart.

B. Participatory SWOT-AHP Model Construction

The key objective of this stage is to convert stakeholders' qualitative insights into measurable policy priorities. The process starts with identifying SWOT factors. Five groups—government officials, farmer representatives, agricultural enterprises, research institutions, and NGOs—participated in structured workshops. Through discussion and consensus-building, eight key factors influencing rural sustainable innovation were identified (see Table I).

These include strengths such as strong information network coverage (S1) and a solid regional education base (S2); weaknesses like insufficient innovation service capacity (W1) and outdated skills among extension personnel (W2); opportunities such as growing demand for multidisciplinary training (O1) and increased availability of specialized advisory services (O2); and threats including intensified market competition (T1) and insufficient financial support for innovation (T2).

The next step involves calculating the relative importance of these factors using the Analytic Hierarchy Process (AHP). Participants performed pairwise comparisons using Saaty's 1 – 9 scale, forming a judgment matrix to represent the relative importance between factors. By computing the matrix's maximum eigenvalue and corresponding eigenvector, weights for each factor were derived. A consistency check was then conducted using the consistency ratio (CR). When CR is below 0.1, the judgments are considered sufficiently consistent, ensuring the reliability of the results.

TABLE I. SWOT FACTORS IDENTIFIED THROUGH MULTI-STAKEHOLDER WORKSHOPS

Strengths (S)	**Weaknesses (W)**
S1: Broad information network coverage	W1: Insufficient sustainable innovation services
S2: Good regional education base	W2: Outdated skills of extension personnel
Opportunities (O)	**Threats (T)**
O1: Continuous multidisciplinary training demand	T1: Intensified agricultural product market competition
O2: Increased supply of specialized advisory services	T2: Inadequate financial support for agricultural innovation

C. Field Experiment Design

To evaluate the practical relevance of the proposed framework, the study collected implementation-oriented feedback from stakeholders in a representative agricultural county in East China. Based on workshop outcomes, policy discussions focused on key themes such as financial support, training quality, service provision, and market connections.

Rather than adopting a more complex experimental design, the study uses a practice-based assessment approach to compare stakeholder perceptions under participatory policy design. A total of 172 valid responses from farmers and agricultural cooperatives were analyzed. The evaluation focuses on three main indicators: the adoption rate of sustainable innovations (measured as the share of land applying green technologies or practices), policy satisfaction (measured on a 1 – 5 Likert scale), and the rate of increase in economic benefits (based on reported income changes per unit area). These indicators are used primarily for descriptive comparison and interpretation, rather than for establishing causal relationships.

D. Data Analysis Methods

The quantitative analysis relies mainly on descriptive statistical methods. The focus is on summarizing stakeholder evaluations, identifying priority factors within the SWOT-AHP framework, and comparing patterns across key policy dimensions such as innovation adoption, satisfaction levels, and economic outcomes. For multi-dimensional indicators like satisfaction, visual comparisons are used to highlight differences in stakeholder perceptions. Consistent with the exploratory and practice-oriented nature of the study, the analysis prioritizes interpretation and practical insights over strict causal inference.

IV. USING THE TEMPLATE

A. Data Sources and Basic Information

The data used in this study come from two main sources. The first consists of questionnaire-based scoring data for the AHP analysis, with a total of 150 valid responses. These responses represent a mix of stakeholder groups, including farmers (40%), government representatives (20%), enterprises (20%), research institutions (10%), and NGOs (10%). The second dataset focuses on practice-oriented policy feedback, comprising 172 valid responses collected from farmers and agricultural cooperatives.

Data collection took place over a one-year period, from March 2024 to March 2025. Before analysis, the dataset was carefully cleaned to remove incomplete or invalid responses, ensuring the overall reliability of the results. These data serve as the basis for identifying priority factors and supporting the descriptive interpretation of policy outcomes.

B. Baseline Data Characteristics and Preprocessing

After preprocessing, the dataset showed reasonable variation across key indicators, making it suitable for descriptive comparison and policy analysis. Table II summarizes the main characteristics of the policy feedback data.

The results indicate that Group B has a slightly higher baseline adoption rate of sustainable innovations (16.91%) compared to Group A (14.61%). In terms of policy satisfaction, both groups report similar levels, with only minor differences (2.64 vs. 2.54 on a 5-point scale). Likewise,

the baseline economic benefit levels are very close between the two groups, with no meaningful gap observed.

Overall, the differences between Group A and Group B are relatively small and are presented for descriptive purposes only. They are intended to support subsequent interpretation of policy outcomes rather than to establish statistically significant differences.

TABLE II. DESCRIPTIVE CHARACTERISTICS OF THE POLICY FEEDBACK DATA

Indicator	Group A (n=85)	Group B (n=87)	Descriptive Difference
Adoption Rate Baseline (%)	14.61 ± 5.05	16.91 ± 4.27	Group B slightly higher
Policy Satisfaction Baseline (1-5)	2.54 ± 0.65	2.64 ± 0.52	Very small difference
Economic Benefit Baseline (%)	5.23 ± 1.77	5.06 ± 1.80	Very small difference

V. RESULTS

A. SWOT Factor Weights from Stakeholder Perspectives

The AHP results based on 150 stakeholder questionnaires passed the consistency test, with a consistency ratio of CR = 0.082 (< 0.1), indicating that the weighting results are reliable. As illustrated in Figure 2, external factors — particularly threats (T) and opportunities (O)—dominate the overall weight distribution. Among all factors, "inadequate financial support for agricultural innovation (T2)" stands out as the most critical constraint, with a global weight of 0.252. This is followed by "intensified market competition for agricultural products (T1)" at 0.168 and "increased availability of specialized advisory services (O2)" at 0.156.

In comparison, internal factors carry relatively less weight. For instance, "outdated skills of extension personnel (W2)" and "good regional education base (S2)" have equal importance (both 0.095). Overall, these findings suggest that stakeholders perceive external pressures — especially financial limitations and market competition—as the primary barriers to advancing rural sustainable innovation, outweighing internal resource conditions.

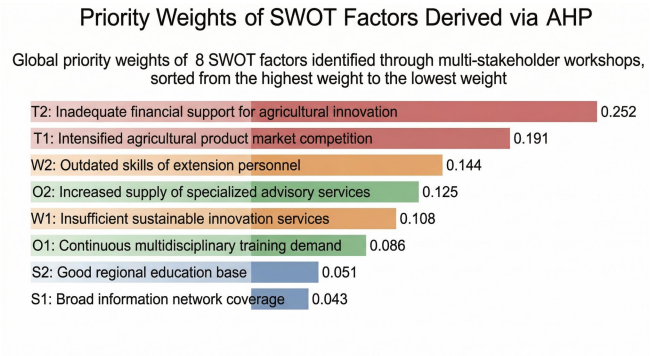

Fig. 2. Priority Weights of SWOT Factors Derived via AHP.

TABLE III. DESCRIPTIVE COMPARISON OF KEY POLICY-RELATED OUTCOMES

Indicator	Group A (n=85)	Group B (n=87)	Observed Pattern
Innovation Adoption Rate (%)	19.66 ± 5.60	35.20 ± 6.42	Group B higher
Policy Satisfaction (1-5)	2.70 ± 0.75	3.84 ± 0.64	Group B higher
Economic Benefit Increase (%)	7.20 ± 2.23	13.36 ± 3.22	Group B higher

B. Descriptive Comparison of Policy-Related Outcomes

The descriptive comparison of key policy outcomes (Table III and Figure 3) reveals clear differences between the two groups. Group B consistently outperforms Group A across all indicators. Specifically, the innovation adoption rate in Group B reaches 35.20% (± 6.42%), significantly higher than Group A's 19.66% (± 5.60%). Similarly, the reported increase in economic benefits is greater in Group B (13.36% ± 3.22%) compared to Group A (7.20% ± 2.23%).

Policy satisfaction also shows a notable gap, with Group B scoring 3.84 (± 0.64) versus 2.70 (± 0.75) in Group A. These patterns suggest that participatory policy design is associated with better alignment between policy measures and stakeholder needs, particularly in terms of encouraging innovation adoption, improving perceived usefulness, and enhancing responsiveness during implementation.

Although Table IV reports statistical indicators (e.g., t-values and effect sizes), these results should be interpreted cautiously, as the study is primarily descriptive and not designed for strict causal inference.

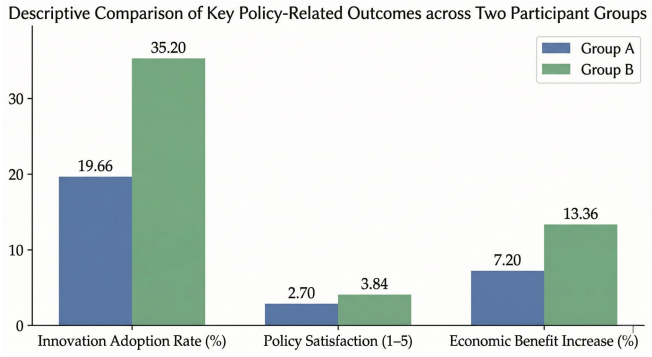

Fig. 3. Descriptive Comparison of Key Policy-Related Outcomes across Two Participant Groups.

TABLE IV. SWOT FACTOR GLOBAL PRIORITY WEIGHTS (OP-SWOT)

Indicator	Control (n=85)	Group B (n=87)	t-value	p-value	Cohen's d
Innovation Adoption Rate (%)	19.66 ± 5.60	35.20 ± 6.42	-16.90	<0.001	2.58
Policy Satisfaction (1-5)	2.70 ± 0.75	3.84 ± 0.64	-10.72	<0.001	1.63
Economic Benefit Increase (%)	7.20 ± 2.23	13.36 ± 3.22	-14.57	<0.001	2.23

C. Radar Chart Analysis of Multi-Dimensional Satisfaction

A more detailed breakdown of satisfaction across five policy dimensions (Figure 4) shows that Group B receives

higher ratings in every category compared to Group A. However, one notable pattern emerges: even within Group B, "financial support" remains the lowest-rated dimension (3.5 points), despite being significantly higher than Group A's rating (2.0 points).

This finding closely aligns with the SWOT-AHP results, where "inadequate financial support" was identified as the most critical constraint. It suggests that financial limitations continue to be a key bottleneck in rural sustainable innovation, even when participatory approaches are introduced. In other words, while participatory governance improves overall satisfaction, it does not fully resolve structural funding challenges.

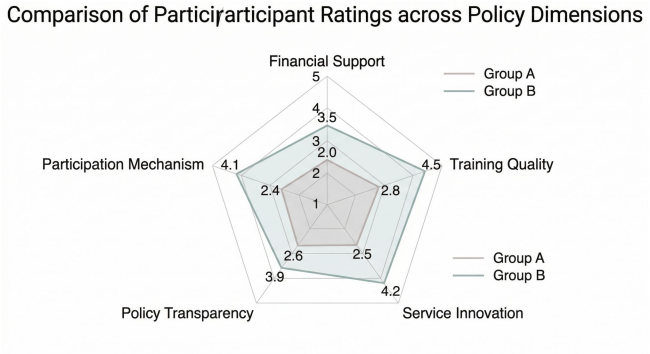

Fig. 4. Comparison of Participant Ratings across Policy Dimensions.

D. Distribution Characteristics of Pre- and Post-Intervention Changes

Figure 5 provides a visual comparison of the distribution of key indicators across the two groups. The results show that Group B consistently demonstrates higher central tendencies across all major metrics. This reinforces the earlier observation that participatory policy design is more closely aligned with stakeholder expectations and practical needs.

Taken together, these findings highlight the value of incorporating stakeholder participation into policy design. While not establishing causal relationships, the results offer strong descriptive evidence that participatory approaches can enhance policy relevance, improve perceived outcomes, and better match real-world implementation conditions.

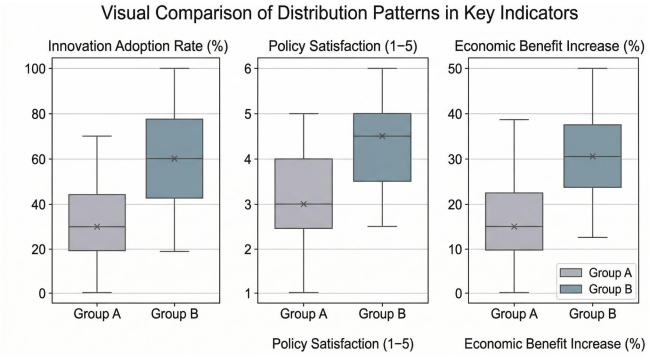

Fig. 5. Pre- and Post-Intervention Distribution by Group.

VI. Discussion

A. Interpretation of Results and Horizontal Comparison

The findings of this study highlight the practical value of participatory policy design grounded in multi-stakeholder collaboration. This aligns with experiences from the European Union's CLLD initiatives. For example, Pollermann et al. (2014), in their analysis of the LEADER program, emphasized that Local Action Groups (LAGs) can effectively combine local knowledge with external resources. Similarly, the results here suggest that participatory approaches enable key stakeholder concerns — such as training quality, service provision, and financial support—to be incorporated into the policy agenda at an earlier stage. Compared to traditional top-down models, this approach appears better suited to capturing local needs and reducing mismatches between policy design and on-the-ground realities.

B. Longitudinal Associations and Internal Logic

The results also reveal a consistent internal logic across different stages of the study. The constraints and opportunities identified through the SWOT-AHP analysis—particularly those related to market competition, advisory services, training, and financial support—closely align with the policy dimensions later emphasized by participants. This consistency suggests that participatory diagnosis plays a meaningful role in improving the alignment between policy supply and stakeholder demand.

In this context, higher levels of policy satisfaction can be interpreted as reflecting improved relevance and responsiveness in policy design. This observation is in line with broader theoretical perspectives, which argue that participatory processes help institutionalize innovation and that their effectiveness depends on how well they are embedded within existing governance structures.

C. Attribution of Differences and Discussion of Outliers

One particularly notable finding concerns the "financial support" dimension. Although ratings for this aspect improved under the participatory framework, they still lag behind those for softer service-related dimensions, such as training and advisory support. This indicates that while participatory governance can enhance communication, prioritization, and service delivery, it does not automatically resolve deeper structural issues—especially those related to funding constraints in rural innovation systems.

As such, participatory governance should not be seen as a comprehensive solution to all policy challenges. Its primary contribution lies in improving policy relevance, coordination, and responsiveness within existing institutional and resource limitations, rather than directly overcoming those limitations.

VII. Conclusion

A. Core Conclusions

This study develops a multi-stakeholder collaborative policy design mechanism based on the SWOT-AHP framework and explores its practical value in promoting rural sustainable innovation. The results suggest that participatory governance can effectively address some of the blind spots associated with traditional top-down policy approaches. By making stakeholder needs more visible and systematically translating them into policy priorities, this approach helps bridge the gap between policy design and real-world conditions. In particular, identifying and incorporating tacit stakeholder demands emerges as a key pathway for

improving policy relevance, responsiveness, and feasibility during implementation.

B. Research Implications

From a theoretical perspective, this study contributes to the literature on Agricultural Knowledge and Innovation Systems (AKIS) by moving participatory governance from a largely conceptual idea toward a more operational decision-support framework. It demonstrates how structured stakeholder engagement can be embedded into policy design in a systematic way.

From a practical standpoint, the study offers a relatively flexible and applicable toolkit for policymakers working on rural revitalization, particularly in developing country contexts. It suggests a shift in the role of policymakers — from being sole decision-makers to acting as facilitators and coordinators. Through structured participation, policymakers can better align policies with local needs, foster consensus among stakeholders, and enhance responsiveness during implementation.

C. Research Limitations

Despite its contributions, the study has several limitations. First, it is based on data from a single agricultural county in East China, where local conditions may be relatively favorable. This means that caution is needed when applying the findings to regions with different socioeconomic or institutional contexts.

Second, the study relies primarily on workshop-based assessments and descriptive feedback. While this approach is useful for identifying priorities and generating practical insights, it does not provide strong causal evidence regarding long-term policy impacts. As such, the findings should be interpreted as exploratory rather than definitive.

D. Future Research Directions

Future research can build on this work in several ways. One direction is to conduct comparative studies across different regions to test how well the proposed framework performs under varying economic, social, and institutional conditions. Another is to further develop simple, scalable evaluation methods for participatory policy design, such as repeated stakeholder surveys, small-scale comparative case studies, or the use of digital tools to support consultation processes.

In particular, digital platforms hold promise for lowering the cost of participation and expanding stakeholder engagement, making participatory approaches more accessible and easier to implement in diverse rural settings.

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AVAILABILITY OF DATA

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AUTHOR CONTRIBUTIONS

Yuhua Li: Conceptualization, methodology, investigation, data curation, and writing—original draft preparation.

Jiankun Peng: Formal analysis, visualization, and writing—review and editing.

Liping Feng: Supervision, project administration, resources, and writing—review and editing.

COMPETING INTERESTS

The authors declare no competing interests.