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The enabling environment for upscaling integrated rice-shrimp systems in the Mekong River Delta of Vietnam

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Integrated rice-shrimp (IRS) farming is commonly practiced in the Vietnamese Mekong Delta (VMD) region. When properly managed, IRS systems can provide farmers in saline-affected areas opportunities to produce food and generate income throughout the year. IRS systems are considered potential solutions to climate change adaptation and mitigation. This study employs a tailored Integrated Assessment Framework for Upscaling to investigate the feasibility and enabling conditions for successful scaling out of IRS systems in the VMD. Our findings indicates that IRS systems has already been widely adopted among the coastal provinces in the VMD, suggesting strong potential for scaling up to broader impacts. IRS systems offer notable environmental benefits and enhance economic resilience for local communities, though their social implications are less understood. Institutional conditions and local commitments strongly support the development and scaling of IRS systems, with stakeholders widely acknowledging their importance. Furthermore, extensive technical and economic data support the systems' expansion. However, our study highlights several challenges that hinder the broader scaling of IRS systems, such as limited financial capacity, fragmented small-scale operations, and the weak role of farmer organizations. Market access, brand development, and value chain coordination remain underdeveloped. At the same time, irrigation infrastructure is poorly aligned with the dual requirements of rice and shrimp aquaculture production during the dry and rainy seasons. This study recommends that targeted financial mechanisms, strengthened farmer organizations, improved market coordination, and upgraded infrastructure are essential to fully realize the potential of IRS systems as sustainable and climate-resilient models in the VMD.

KEYWORDS

integrated rice-shrimp system, innovative scaling, Mekong River Delta, climate change, resilience, sustainable development

Highlights

- Scaling readiness analysis suggests that the Integrated Rice-Shrimp (IRS) system has significant potential for large-scale impact in the Vietnam Mekong Delta (VMD).
- The IRS system provides notable environmental benefits and economically supports more sustainable livelihoods.
- However, key barriers include limited financial capacity, fragmented small-scale operations, the weak role of farmer organizations, restricted market access, underdeveloped branding, and insufficient value chain transparency.

- Addressing these challenges will be essential to unlocking the IRS system's full potential in the VMD.

1 Introduction

The global food system supports nutrition, livelihoods, and income for millions of people, but is also a major driver of adverse environmental impacts such as water scarcity, soil erosion, droughts, biodiversity loss, pollution, overfishing, and greenhouse gas emissions (Springmann et al., 2018). The system generates about one-third of annual global anthropogenic greenhouse gas (GHG) emissions, with 71% coming from agriculture, land, and land-use change activities, while the rest originates from supply chain activities like transportation, retail, consumption, and waste management (Crippa et al., 2021). Traditionally, global food system debates have often focused on terrestrial food systems (e.g., agriculture and livestock); however, in recent years, there has been an increased recognition of the importance of aquatic food systems, particularly aquaculture, as a dynamic sector contributing to sustainable food system transformation. Practiced in freshwater, brackish, and marine water environments, aquaculture supports food security, rural livelihoods, and socio-economic development, offering highly nutritious aquatic foods with a lower environmental impact compared to terrestrial animal-based products (Crona et al., 2023; Troell et al., 2023). Aquaculture has been the fastest-growing food production sector in the world for more than 30 years, catalyzing global food systems in developing countries to shift toward sustainable and nutrition-sensitive food systems.

Mega Deltas in Asia support diverse and productive terrestrial and aquatic food systems, of which rice farming and fish and shrimp aquaculture play essential roles in food, nutrition, and income generation for the deltas' residents. Marine and brackish aquaculture production systems typically predominate in coastal zones and estuaries, whereas terrestrial production systems and freshwater aquaculture systems dominate the inner areas of deltas. The intersection between terrestrial and aquatic food production systems is the integrated agricultural aquaculture (IAA) system, which has been practiced in Asian mega deltas for thousands of years. This system represents a promising approach to addressing global environmental and socio-economic challenges, supporting the transformation to a low-emission food system, ensuring food security, and enhancing rural livelihoods. By combining crop (rice, vegetables, and fruits) and aquaculture production (fish and or shrimp) within the same system, these practices optimize resource use, enhance nutrient cycling, and reduce environmental impacts (Ignowski et al., 2023). For instance, aquaculture waste can serve as organic fertilizer for crops, minimizing the need for chemical inputs and reducing GHG emissions (Farrant et al., 2021).

The Mekong Delta region in Vietnam (VMD) has an area of 3.9 million hectares and is home to thriving aquatic and terrestrial food production systems (Li et al., 2017; Tran et al., 2021). It is considered one of the most vulnerable deltas to climate change, facing severe challenges from rising sea levels, saltwater intrusion, and extreme weather events. Agriculture and aquaculture are crucial to the country's food security, rural livelihoods, and economic growth; however, they both contribute to and are significantly impacted by climate change (Tran et al., 2022). Integrated rice shrimp (IRS) farming in the VMD

has a rich history spanning nearly half a century (Preston and Clayton, 2003). The origins of the IRS system date back to the 1970s, when coastal communities in the VMD began supplementing their rice fields with natural shrimp seeds sourced from tidal streams during the dry season, a period when traditional rice production is less viable (Preston and Clayton, 2003). A significant turning point of the IRS system occurred in the early 1990s with the introduction of black tiger shrimp (*Penaeus monodon*) into rice fields, enabled by advances in artificial production of black tiger shrimp seed. The transition to shrimp cultivation in the VMD was further propelled by increasing global market demand, declining rice prices, increased saltwater intrusion, and the seasonal influx of shrimp postlarvae during saline periods. As a result, integrated rice-shrimp farming systems began to take shape in the VMD by the late 1980s (Nhuong et al., 2002). The estimated area under IRS farming has since expanded from 5,000 hectares in 1984 to 153,000 hectares in 2014 (Loc et al., 2021) reflecting the growing significance of IRS to the region's agricultural landscape.

IRS farming systems are commonly practiced by farmers in coastal provinces in the VMD as effective options to adapt to climate change (Hua et al., 2025). Recognizing the intertwined importance of these systems, Vietnam has identified the Integrated Rice-Shrimp (IRS) system as one of the important measures for adapting and mitigating the negative impacts of climate change in the VMD. IRS is included in the Nationally Determined Contributions (NDC) as a potential option to reduce GHG emissions in agriculture, mainly rice farming, in the VMD. The Ministry of Agriculture and Rural Development (MARD) reinforced this commitment through Decision 3,550/QĐ-BNN-TCTS, issued on August 2, 2021, to expand the IRS system to 250,000 hectares by 2030 (MARD, 2021). This initiative promotes a balanced approach to reducing GHG emissions while advancing economic development, food security, and climate resilience in rural communities in the VMD.

Successfully implementing this ambitious plan requires a comprehensive understanding of IRS systems, the enabling environment for scaling up these systems, and how this scaling process contributes to achieving sustainable development goals at the delta-wide level. This involves an in-depth analysis of the IRS systems' dynamics, typologies, and technical characteristics within the region, along with a robust analysis of the scaling readiness and its impacts on sustainable development. Our literature review reveals that no prior studies have comprehensively assessed the enabling environment required to scale up the IRS system across the entire VMD successfully. Existing research on IRS systems primarily focuses on micro-level performance evaluations, addressing technical, socio-economic, and environmental aspects. One of the earliest IRS studies in the VMD was conducted through three longitudinal research projects funded by ACIAR between 1995 and 2002 (Petersen and Hua, 2022). These projects contributed to understanding the economics of IRS (Be et al., 1999; Brennan et al., 2002; Tran et al., 1999) and the system's environmental impacts (Burford et al., 2020). The most comprehensive review of ACIAR's work during this period by Preston and Clayton (2003), analyzed socioeconomic factors, technical aspects like rice variety selection, and environmental issues like land loss. Another ACIAR-funded project (2013–2019) led to a series of studies that explored the biophysical factors influencing IRS systems, risk factors in rice and shrimp production, and shrimp nutrition budgets (Sammut and Nguyen, 2020). In addition to ACIAR's publications, some case studies have assessed IRS systems in terms of climate change

adaptation (Poelma et al., 2021), sustainability (Dang, 2020), and impacts on soil quality (Kruse et al., 2020; Ngo et al., 2023).

Despite these contributions, significant research gaps remain in scaling IRS systems, particularly in addressing temporal and system-level dynamics, reciprocal interactions with external factors, alignment with development goals, inclusivity, and the lack of comprehensive evaluation frameworks. Existing studies largely lack longitudinal analyses to assess how IRS systems evolve and adapt to climatic, socio-economic, and environmental changes. At the system scale, insufficient research exists to understand interactions between scaling IRS systems and broader delta-wide processes, such as water resource management, land use changes, and ecosystem health. Moreover, the two-way impacts of IRS systems on Sustainable Development Goals (SDGs) remain underexplored, with limited attention to potential trade-offs, such as those between climate action (SDG 13), clean water and sanitation (SDG 6), and economic growth (SDG 8). Inclusivity is another underrepresented area, with little focus on ensuring equitable benefit-sharing and active participation of diverse groups, including women and marginalized communities. Additionally, the absence of multi-dimensional indicators to evaluate scaling conditions restricts assessments to narrow economic or environmental outcomes, neglecting social, institutional, and cultural dimensions. Addressing these gaps is critical to ensure that the expansion of IRS systems supports sustainable development and resilience in the VMD.

This research aims to address these gaps by developing a comprehensive approach, the *Integrated Assessment Framework for Upscaling*, for assessing scaling ambitions, capacities, bottlenecks, opportunities, and the conditions necessary for the sustainable and responsible scaling of IRS systems in the VMD. The combined

framework is a robust tool for evaluating the readiness and feasibility of scaling while incorporating environmental, social, and institutional dimensions.

The study focuses on answering two main research questions:

- 1 How feasible is the scaling of the IRS system, considering its readiness and contributions to development goals?
- 2 What enabling conditions are required to scale the IRS system in the VMD successfully?

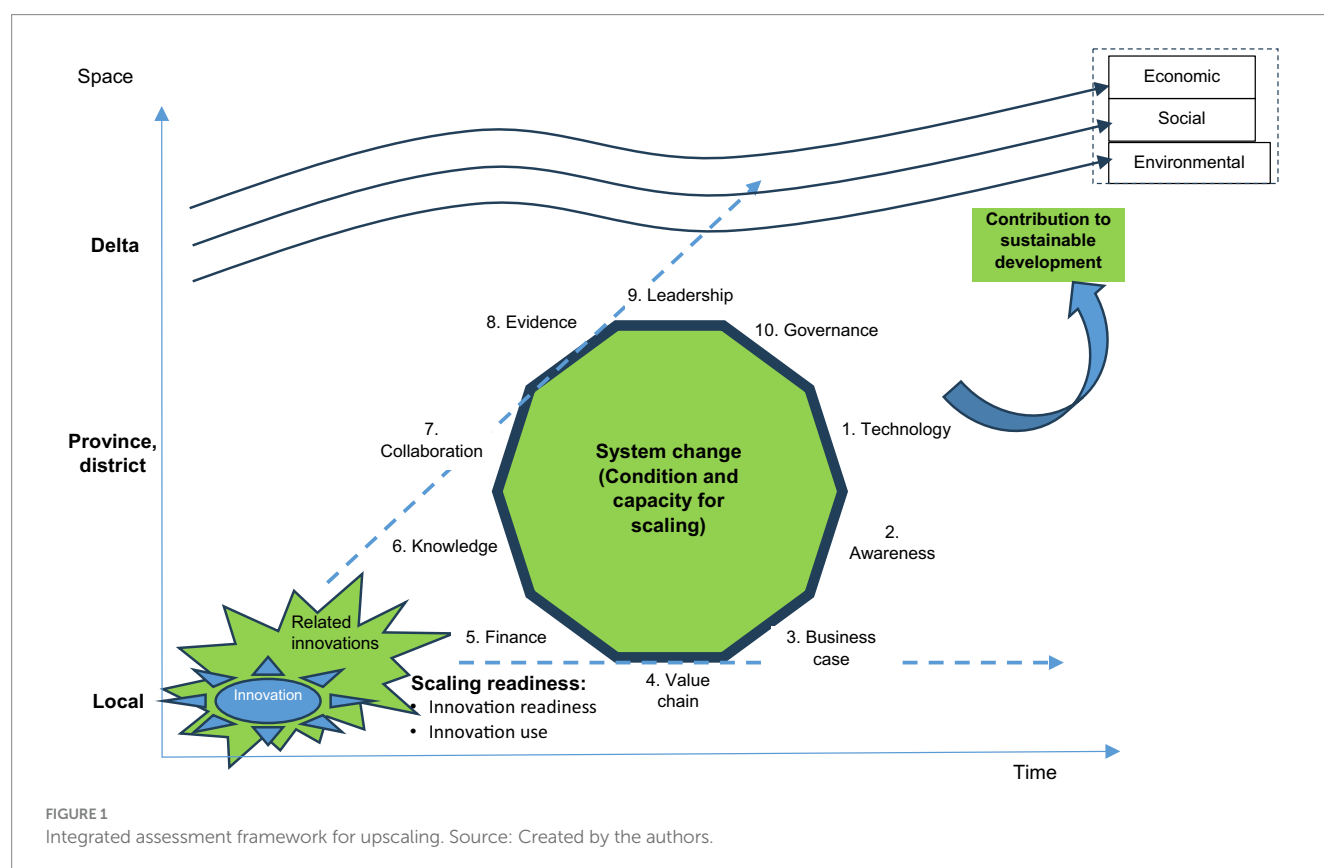
2 Materials and methods

2.1 Analytical framework

To evaluate the success of scaling the IRS system in the VMD, we have developed and applied a novel framework - the Integrated Assessment Framework for Upscaling, as illustrated in Figure 1. This framework builds upon the Capacity for Scaling Innovation (C4SI) framework proposed by (Wigboldus et al., 2023), providing a conceptual foundation for understanding the scaling process across both temporal and spatial dimensions.

The framework integrates a range of tools and methodologies to conduct two primary analyses:

- (i) Assessing the Feasibility of Scaling the IRS System in the VMD
 - o Evaluating Scaling Readiness: Assess the readiness for scaling the IRS system in the VMD using the Scaling Readiness tool proposed by (Sartas et al., 2020).

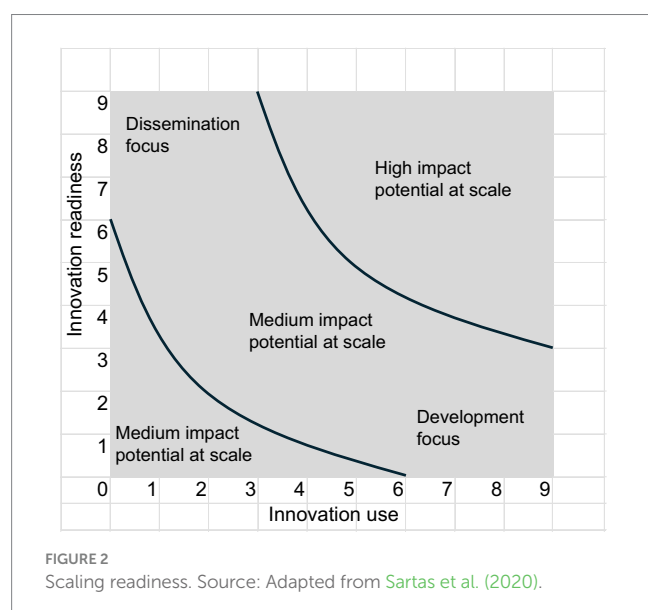


- o Exploring Contributions to Sustainability: Investigate how the scaling process contributes to sustainable development by extending the Responsibility Check component of the Scaling Scan tool (Woltering and Alvarado, 2021) and incorporating elements of Responsible Scaling as proposed by (Wigboldus and Leeuwis, 2013).
- (ii) Evaluating the Enabling Environment for Successful Scaling
 - o If scaling the IRS system in the VMD is feasible, assess the enabling environment necessary for successful scaling using the Scaling Scan tool developed by (Woltering and Alvarado, 2021).

2.1.1 Assessing scaling readiness

The first component of this framework involves evaluating the scaling readiness of the IRS system in the VMD (Figure 2). For this study, we utilized Step 2 (*Diagnose*) from the five-step Scaling Readiness tool proposed by Sartas et al. (2020), which includes *Characterize, Diagnose, Strategize, Agree, and Navigate*. Step 2 was selected because it specifically focuses on assessing the scaling readiness of an innovation within its scaling context, aligning with the objectives of this research.

The scaling readiness level is conceptualized as a function of *innovation readiness* and *innovation use*. The term “innovation readiness” refers to the demonstrated capacity of an innovation to deliver its intended outcomes or contribute to specific development objectives. The level of innovation readiness increases as the innovation evolves—from an untested concept to one validated in a controlled environment (e.g., a laboratory or project setting) and, ultimately, to a fully matured innovation proven effective under real-world, uncontrolled conditions. The concept of “innovation use” is employed to measure the extent to which the IRS system has penetrated networks and expanded within the VMD. Based on the scaling readiness level, the IRS system can be categorized into one of three zones: *low impact potential at scale*, *medium impact potential at scale*, or *high impact potential at scale* (Figure 2).



scale, medium impact potential at scale, or high impact potential at scale (Figure 2).

2.1.2 Assessing the contribution of the scaling process to sustainable development

The second component examines how the scaling of the IRS system contributes to the sustainable development of the VMD, emphasizing the balance among three key pillars: environmental protection, social development, and economic prosperity. On this basis, we conducted expert consultations to gather qualitative feedback on the potential consequences of scaling the IRS system across three dimensions: economic, social, and environmental. Economic considerations included factors such as production costs, profitability, and resilience to market fluctuations. Social aspects encompassed gender equality, age inclusiveness, social equity, and community resilience. Environmental dimensions focused on water usage and quality, climate change mitigation, chemical use, and waste management. Comparisons were made between the IRS system and the prevalent systems it is likely to replace, enabling a comprehensive assessment of the relative impacts of scaling the innovation.

2.1.3 Assessing the enabling environment for scaling

After assessing the feasibility of scaling the IRS system, we employed the *Scaling Scan* framework (Woltering and Alvarado, 2021) to understand better the enabling environment necessary for scaling the IRS system in the VMD. At the core of the Scaling Scan is a scalability assessment tool that integrates 10 critical scaling “ingredients” (e.g., *Finance, Collaboration, and Awareness & Demand*; see Table 1), each representing distinct sets of professional activities. These ingredients were identified as critical for successful scaling through expert interviews conducted by Ubels and Jacobs (2016). Unlike other scaling frameworks, such as Rogers’ Diffusion of Innovations (2003), which focus extensively on the attributes of the innovation itself, nine of the 10 ingredients emphasize the non-technological conditions that determine whether the surrounding system is conducive to scaling (*scale-friendly*), as noted by Woltering et al. (2019).

The Scaling Scan is a practical and accessible tool we translated from English into Vietnamese, enabling structured and rapid feedback from local stakeholders on key scaling issues. Each ingredient is assessed through four tactical questions, incorporating critical international lessons on scaling and guiding users in evaluating gaps between scaling objectives and on-the-ground realities. The tool adopts a semi-quantitative approach: users rate each question, resulting in an average indicator score for each ingredient on a scale from 1 (*poor status*) to 5 (*very conducive to scaling*). This scoring system helps identify which scaling ingredients present bottlenecks for successful scaling.

2.2 Methodology

Following the scaling readiness framework outlined in Part 2.1.1, the project team collected background information through a comprehensive, desktop-based review, gathering data, information, and evidence regarding the readiness and use of the IRS system. This

TABLE 1 Indicators for the scaling scan tool and description.

Indicator	Description
Technology/practice	The IRS system should be relevant, compatible, easy to adopt, and better than alternatives that address the problem of the target population.
Awareness and demand	Farmers, service providers, and machinery companies should be aware of the technologies and service provider arrangements and demand their use.
Business case	Attractive financial/economic propositions for companies, service providers, and other actors should be in place to respond to the demand for mechanization service providers
Value chain	Effective links between value actors should exist for them to pursue the business cases for mechanization and service providers
Finance	Effective and low-risk financing options for users and other value chain actors should be available
Knowledge and skills	Individual- and institutional-level capacity should be sufficient to use, adapt, and promote the innovation
Collaboration	Strategic collaboration within and beyond the sector is required to scale machinery and service provider businesses beyond the project context.
Evidence and learning	Evidence and facts (data, scientific insights) are available to underpin and help gain support for the pursuit of the scaling ambition
Leadership and management	Effective coordination and navigation of the scaling process by machinery and service provider “champions” and brokers help propel scaling forward.
Public sector governance	Government support and/or lack of prohibitive policies are necessary to achieve the scaling ambition.

Source: Adapted from Woltering and Alvarado (2021).

review drew on academic literature, technical databases, relevant repositories, and project reports.

To implement the steps outlined in Part 2.1.2. and 2.1.3, a workshop was held in Can Tho City, the central hub of the VMD, in November 2024. The workshop included 16 participants from five key sectors: regional government representatives, business stakeholders, university and research institute experts, farmer group leaders, and NGO project collaborators. Participants were selected based on their in-depth experience and knowledge of the IRS system, ranging from 10 to 15 years, to ensure the provision of insightful information. Expert selection is also to ensure that representatives from provinces and districts where IRS farming plays a significant role are included in the consultation workshop. Special care was taken to avoid technical language barriers and to facilitate effective communication.

The workshop, facilitated by three research team members without direct involvement in individual IRS projects, lasted approximately 4 h. One researcher introduced the System Transformation Assessment Framework for Upscaling (Figure 1). Following this, the research team and participants discussed the current state of IRS systems in the VMD, qualitatively assessing both the IRS use and readiness for scaling up.

The discussion then transitioned to the contributions of the IRS system upscaling plan to the sustainable development of the delta. Experts ranked the upscaling impact on economic, social, and environmental pillars. Additionally, the feasibility of the proposed scaling-up plan was assessed through an online questionnaire, where participants rated feasibility on a scale ranging from “Very feasible” to “Not feasible.”

After the feasibility assessment, the research team examined the enabling environment necessary for scaling up the IRS system in the VMD (Table 2). Experts provided evaluations through a smartphone questionnaire. Indicator scores for the Scaling Scan were derived by averaging the scores from the four corresponding tactical questions, providing an aggregate score for each ingredient. The research team facilitated discussions with experts on three key areas: (i) the criteria with the lowest score, the criteria with the most significant score differences, and (iii) the criteria with the highest scores. Using the *problem tree* method, the team organized a session to list all policy recommendations for these criteria groups on large A0 sheets to solicit expert feedback. Finally, a selection process was conducted via a smartphone questionnaire, where experts identified the five most important policy recommendations.

In addition to the expert consultation workshop, the study also heavily draws on quantitative and qualitative data collected by previous projects led by the research team (first and second authors). Comprehensive reviews of results published by other studies investigating different aspects of the IRS farming are also conducted to triangulate the expert consultation findings, ensuring that elements of scaling dynamics are covered in presenting and discussing the study findings.

3 Results and discussion

3.1 Scaling readiness of IRS in VMD

3.1.1 Innovation use

IRS farming in the VMD has evolved over five decades, transitioning from opportunistic shrimp seeding to diversified, structured farming systems. Review of research reports related to IRS in VMD indicates a multitude of IRS systems in the VMD, and this diversity has been on the rise over time (Pham and Trinh, 2016; Trinh and Trinh, 2022). Before 2012, the dominant IRS farming approach in VMD followed the traditional model of one black tiger shrimp (*P. monodon*) crop followed by one rice crop, with multiple shrimp seed stockings (typically 2–3 times per shrimp crop). Since 2012, some households have adopted the cultivation of white leg shrimp (*L. vannamei*) in variations such as two white-leg shrimp crops followed by one rice crop or one black tiger shrimp crop followed by one white leg shrimp crop and one rice crop. Furthermore, starting from 2014, giant freshwater prawns were introduced into intercropping practices during the rice crop, resulting in substantial improvements in the model's efficiency. Mud crabs are also intercropped with black tiger shrimp and white leg shrimp during the shrimp farming season. This diverse array of IRS models can be classified into three primary types: (i) semi-intensive farming with one shrimp crop followed by one rice crop, (ii) semi-intensive farming with two shrimp crops followed by one rice crop, and (iii) improved extensive farming with one shrimp crop followed by one rice crop.

TABLE 2 Change in the IRS land use area in VMD between 2018 and 2023.

Province	2018		2023	
	Area	% of total VMD agricultural land	Area	% of total VMD agricultural land
Bac Lieu	43,439	20%	41,541	19%
Ben Tre	5,598	3%	5,360	3%
Ca Mau	38,185	8%	36,822	8%
Kien Giang	102,998	18%	110,038	19%
Soc Trang	9,428	4%	7,913	3%
Tra Vinh	3,529	2%	2,440	1%
All VMD	203,177	11%	204,114	11%

Source: Compiled by the authors.

3.1.2 Innovation readiness

These three IRS models described above exhibit notable differences in technical complexity and investment requirements. Generally, the improved extensive model necessitates fewer infrastructure enhancements and lower investments than the semi-intensive ones. In IRS systems, modifications are made to rice fields to facilitate shrimp stocking. For improved extensive systems, surrounding trenches are constructed with a depth ranging from 1 to 1.2 meters and a width of 2 to 3 meters. In contrast, semi-intensive models typically require surrounding trenches with permanent banks, characterized by a depth of 1.4 to 1.5 meters and a width of 3 to 4 meters. Additionally, semi-intensive models often incorporate additional equipment, such as aerators to enhance oxygen supply for shrimp, or water filter ponds to optimize the aquatic environment for shrimp production. Furthermore, there are distinctions in the feeding practices. Shrimps in the improved extensive farming model primarily rely on natural food sources, while semi-intensive systems depend on industrial feed due to the higher stocking density of shrimp (Pham and Trinh, 2016; MARD, 2022).

All the above information was input into a Microsoft Excel template to plot the Scaling Readiness graph. To validate the results, the research team presented the template to experts for their feedback. The consultation results are also triangulated with available data and information from previous studies whenever possible. The innovation readiness level was assessed at 5, indicating that the IRS system can deliver its intended outcomes in a controlled environment. Meanwhile, the use scores were ranked at 8, reflecting that producers in the VMD have widely adopted the IRS system. These findings suggest that the IRS system has significant potential for impact at scale (Figure 3).

Expert consultations conducted in Can Tho City corroborated these findings. Eighty percent of the experts agreed that the mass-produced IRS system has been widely deployed for an extended period and is popular across most coastal provinces of the VMD. However, in terms of IRS readiness, they highlighted critical challenges. The existing infrastructure, initially designed for rice production, is not well-suited for shrimp farming, which requires separate inflow and discharge water channels to function effectively. Additionally, the current production processes, tailored to standard weather conditions, lack adequate technical solutions to address climate change-induced extreme events, such as unseasonal rainfall, significant temperature fluctuations, and severe salinity intrusion.

3.2 Impact of the IRS system on sustainable development

The impact of the IRS system on sustainable development was qualitatively assessed based on expert opinions gathered during the workshop in Can Tho City (Figures 4, 5). The performance of two widely adopted production systems, namely the 2-crop rice system and the extensive shrimp system, was compared to that of the IRS system. This comparative analysis aimed to provide insights into the relative sustainability benefits of the IRS system across economic, social, and environmental dimensions.

Expert opinions suggest that, compared to the systems it replaces, the IRS system significantly positively impacts the economic and environmental pillars (Figures 4, 5). Experts noted that the IRS system demonstrates greater resilience to climate change, generates lower greenhouse gas (GHG) emissions, and reduces the use of chemicals and overall waste. From an economic perspective, the IRS system is believed to increase product prices and profitability while enhancing farmers' ability to cope with market uncertainties, natural disasters, and diseases. However, experts indicated that the social impacts of the IRS system may be mixed. While it does not improve workload distribution or reduce the burden on female laborers, it contributes positively by supporting farmers in maintaining sustainable livelihoods and enhancing the health of household members.

3.3 Assessing the feasibility of scaling the IRS system in VMD

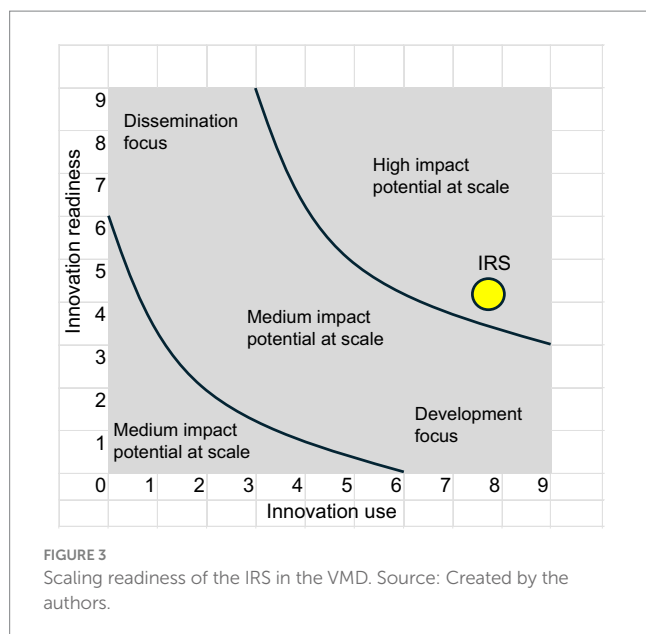
After assessing the scaling readiness, the influence of external factors on scaling, and the contribution of scaling to the sustainable development of the VMD, experts at the Can Tho City workshop provided an overall evaluation of the feasibility of scaling the IRS system. The results indicate that 100% of the experts considered the targeted scaling plan for the IRS system in the VMD to be feasible. However, 34% of the experts described the plan as ambitious and emphasized that its success would depend on strong commitment and coordinated efforts from all relevant stakeholders (Figure 6).

3.4 Assessing the enabling environment required for scaling the IRS system in the VMD

3.4.1 General assessment

Figure 7 provides a comprehensive overview of expert assessments across critical indicators for scaling the IRS system in the VMD, ordered from the highest to the lowest scores. Indicators such as "Public sector governance" and "Awareness & demand" exhibit the highest scores, reflecting strong institutional support, robust stakeholder recognition of the system's value, and demand. These strengths provide a solid foundation for scaling efforts.

Moderately high scores are observed in "Knowledge & skills," "Leadership & management," and "Evidence & learning," indicating capacity in these areas but also room for further enhancement to support scaling effectively. The "Technology & infrastructure" indicator also falls within a moderate range, suggesting that while



technological readiness exists, further refinement and adaptation are necessary for broader implementation.

In contrast, “Collaboration” exhibits relatively low scores, highlighting the need for stronger partnerships and coordinated efforts among stakeholders. With the lowest scores, the “Finance” and “Value chain” indicators signal significant challenges in accessing financial resources and investment and integrating the IRS system into existing market structures and distribution networks. These financial and market-related barriers are major obstacles to scaling.

Overall, while there are clear strengths in Public Sector Governance, Awareness and Demand, and Leadership and Management, addressing gaps in Finance, Value Chains, Collaboration, Technology and Infrastructure, and Market Integration will be critical for the successful scaling of the IRS system. Additionally, some sub-indicators within all indicators require further improvement, which will be discussed in detail in the following section.

3.4.2 Public sector governance

The “Public sector governance” indicator demonstrates strong performance (average score of 3.75), with consistently high scores across its sub-indicators, reflecting a high level of institutional commitment to scaling the IRS system. Both the *participation and commitment of local governments* in promoting the system and the *institutional support level by local and central agencies* for scaling initiatives received the highest possible average scores of 4.00. The development of the IRS system is stated in the NDC as an important strategy to reduce GHG emissions (NDC, 2022). It is also incorporated into the central development plan, such as Resolution 120/NQ-CP (GOV, 2017), the VMD Master Plan (GOV, 2022), the VMD Agricultural Master Plan (GOV, 2020) and Aquaculture Development Plan (GOV, 2021) which emphasizes sustainable and climate-resilient development, promoting adaptive farming systems like the IRS system. At the local level, the provincial governments of the eight largest IRS provinces have incorporated the IRS system into their agricultural development plans. These strategies are considered *well-aligned to create favorable conditions* for scaling the system, with an average score of 3.88.

There are several policies to support the IRS system, with measures including improved irrigation infrastructure, disease-resistant rice varieties, and cooperative models (Trinh, 2020). However, the *policy support level* was assessed to be moderate, with a lower average score of 3.13. Experts highlight that challenges persist in enforcement, resource allocation, and market stabilization mechanisms, emphasizing the need for stronger alignment and targeted support to scale the IRS system effectively. Furthermore, efforts should aim to enhance the integration of these commitments with other ongoing initiatives, ensuring that public sector support delivers tangible benefits for farmers and enterprises. Strengthening monitoring mechanisms to track progress and uphold accountability will be essential to sustaining momentum for scaling the IRS system.

One important observation is the outlier identified in this indicator, which highlights variability in expert opinions. While the overall score for this indicator is high, the outlier reflects concerns about inconsistent implementation and enforcement of policies across different regions. Some provinces may excel in institutional support and policy execution, while others face challenges due to resource constraints or a lack of coordination. This variability underscores the need for a more cohesive governance framework to ensure uniform support for scaling efforts across the VMD.

3.4.3 Awareness and demand

The “Awareness and demand” indicator demonstrates strong perceptions among all stakeholders, highlighting a shared recognition of the urgency and benefits of the IRS system (average score of 3.71). The data shows high scores, particularly for the sub-indicator about *Perception of stakeholders, especially farmers and local governments, about the necessity of transitioning to the IRS system*, which achieves an average score of 3.94. This reflects a consensus on the importance of adopting the system as a response to environmental and economic challenges. Similarly, the sub-indicator about the *demand and willingness to shift to the rice-shrimp system* indicator also scores high (3.81), reinforcing the idea that farmers and other actors are motivated to make the transition.

Moreover, the *effectiveness of information dissemination systems* about the IRS system and *farmers’ ability to access this information* scored relatively high at 3.625, reflecting a well-functioning communication framework. Similarly, the *adequacy of information about different farmer groups, which enables the development of tailored extension programs*, scored 3.562, indicating strong but improvable support for targeted outreach efforts. Although these results highlight that the communication systems are relatively effective, there remains room for improvement in ensuring inclusivity and equity across all farmer groups.

These findings indicate that awareness and demand are not a barrier but a key driver for scaling the IRS system, as stakeholders are already aligned in their understanding of its urgency and value. This shared understanding provides a strong foundation for broader acceptance and adoption across various groups. Research shows that farmers’ awareness of climatic anomalies and environmental sustainability positively influences their willingness to adopt climate adaptation strategies, including transitioning from rice monoculture to systems like IRS (Le et al., 2024). Moreover, this alignment among stakeholders not only drives individual behavioral changes but also fosters collaborative efforts to address challenges collectively (Agbodzakey, 2024). By

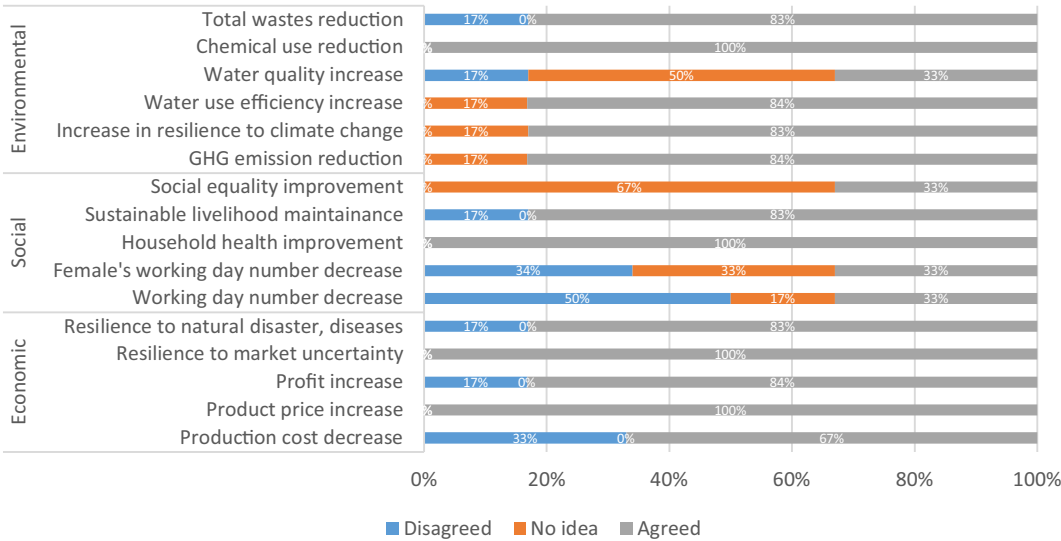


FIGURE 4
Comparing the IRS with the 2-crop rice system-Expert opinion. Source: Expert's consultation results in Can Tho workshop November 2024.

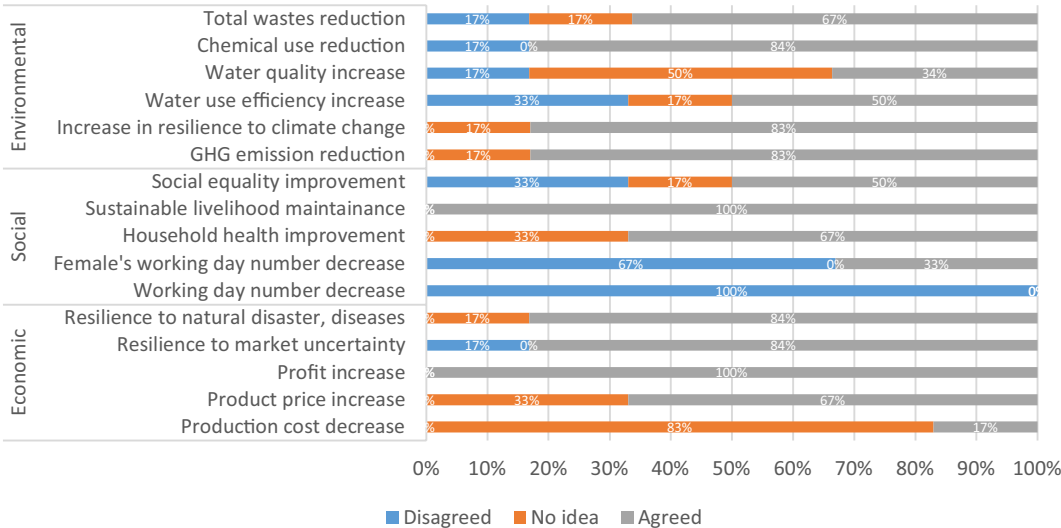


FIGURE 5
Comparing IRS with extensive shrimp system-Expert opinion. Source: Expert's consultation results in the Can Tho workshop, November 2024.

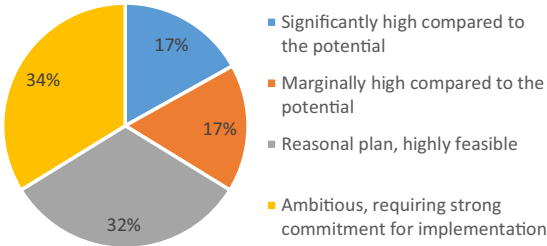


FIGURE 6
Rating the feasibility of scaling IRS systems in VMD. Source: Expert's consultation results in the Can Tho workshop, November 2024.

leveraging these positive perceptions, policymakers and extension services can implement targeted communication and capacity-building programs that emphasize adaptation's environmental and economic benefits. These initiatives will further enhance the scalability and sustainability of the IRS system while strengthening resilience in vulnerable regions.

3.4.4 Knowledge and skills

The "Knowledge & Skills" indicator demonstrates relatively strong performance, with an average score of 3.5. The sub-indicator about the alignment of training materials and programs with the needs of different target groups, considering the sufficiency and relevance of curricula, training methods, and effectiveness, received

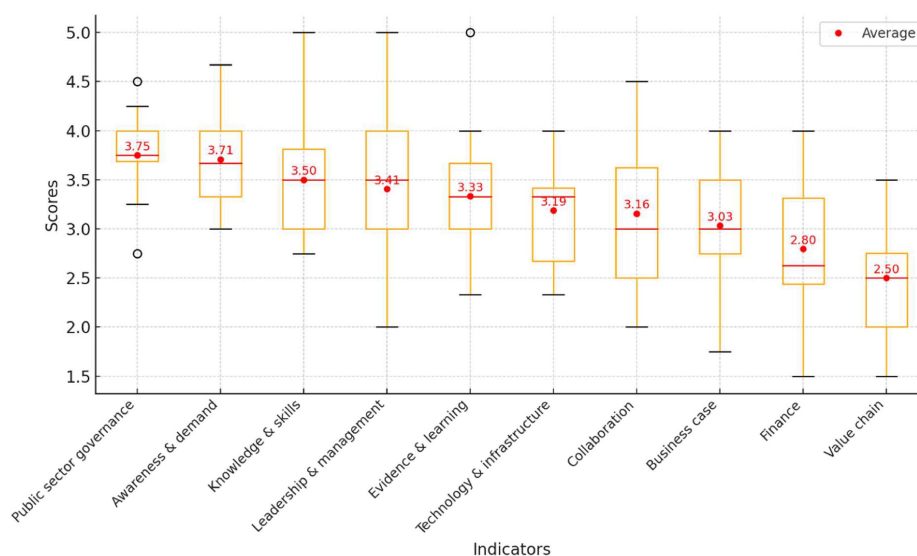


FIGURE 7

Overall assessment of the enabling environment for IRS system scaling in VMD. Source: Expert's consultation results in the Can Tho workshop, November 2024.

an average score of 3.69. At the same time, *the expertise and capacity of participants involved in extension and training activities* also score high at 3.75. This reflects the strength of the extensive agricultural extension system and well-documented technical guidelines for the IRS system. However, *farmers' knowledge and understanding* scored slightly lower, at 3.375, suggesting a moderate level of comprehension. This is consistent with some other studies by Trinh (2020) and Poelma et al. (2021). *The effectiveness of mechanisms facilitating and supporting non-state actors' participation in extension services* scores 3.19, the lowest score among sub-indicators.

These scores indicate that while the existing skills and knowledge infrastructure provides a solid foundation for scaling the IRS system, experts highlight the need to address remaining gaps to ensure its effectiveness across diverse contexts. Tailoring knowledge and skills to the specific needs of different farmer groups is essential to avoid disparities in adoption and implementation (Poelma et al., 2021; Poelma et al., 2021). Efforts should focus on enhancing farmers' understanding of advanced techniques, not only for managing salinity intrusion and water shortages but also for improving productivity, resource efficiency, and market integration (Dang, 2020). Furthermore, strengthening partnerships and engaging non-public sectors can expand the reach and effectiveness of extension services, ensuring more inclusive knowledge dissemination and the adoption of advanced practices across all stakeholder groups (Tran and Touch, 2024).

3.4.5 Leadership and management

The "Leadership and management" indicator demonstrates moderate performance, with an average score of 3.41. Experts have identified enterprises as the primary leaders among key stakeholders in driving the scaling of the IRS system due to their strategic role in connecting farmers to markets, ensuring product quality, and mobilizing resources. Hutton et al. (2021) indicate that agri-business will dominate future agricultural production in the delta. These

businesses often possess the expertise, networks, and financial capacity to drive scaling initiatives effectively (Sadovska et al., 2020).

The capacity of enterprises to *mobilize and engage all relevant parties* in the scaling process scores relatively high at 3.38. Similarly, the ability of enterprises to *share a clear vision and build consensus* among stakeholders scores 3.44. This reflects their strength in forming partnerships and fostering stakeholder commitment. However, the support enterprises *receive from other actors* is still insufficient, with the lowest average score of 3.19 among all sub-indicators. While some enterprises benefit from assistance, this support often lacks consistency and scalability. For enterprises to fully realize their potential as leaders, stronger institutional and policy support is required to enhance their capacity to drive the scaling of the IRS system. This result reflects the broader challenge of weak policies supporting agribusiness in the VMD. Gaps include limited financing for agribusiness, insufficient public-private partnerships, and inadequate support for value chain integration. Existing initiatives focus on production rather than addressing systemic issues such as market linkages and risk-sharing mechanisms (LienLe et al., 2024).

3.4.6 Evidence and learning

The "Evidence & learning" indicator reflects moderate performance, with scores ranging from 3.125 to 3.625 across three key sub-indicators. *The availability and reliability of information and data* score relatively well, averaging 3.625, suggesting that there is a foundational level of both qualitative and quantitative data, including insights on economic, social, and environmental impacts. However, experts highlight that much of this information remains fragmented and scattered among localities and NGOs, making it difficult to consolidate into a cohesive knowledge base.

The application of digital technologies to support information collection, analysis, dissemination, and awareness-raising scores lower, with an average of 3.125. While there are initial efforts to use digital tools for knowledge management, these are not yet systematic or widespread. Many localities lack the infrastructure or expertise to fully

utilize these technologies, which limits their potential for improving efficiency and reach (Nguyen et al., 2023). Moreover, the mechanisms for sharing knowledge and experiences, including IRS, are neither clear nor sustainable, reflecting a broader issue in information dissemination across the Lower Mekong Subregion (McPherson and Ropicki, 2021), leading to gaps in how information is disseminated and utilized by stakeholders.

The effectiveness of monitoring and evaluation systems averages 3.25, reflecting moderate progress in this area. Existing systems provide some guidance for scaling processes and adjustments, but are not yet robust or systematic. Challenges include a lack of comprehensive criteria and methodologies for evaluation, inconsistent data collection practices, and insufficient feedback loops. Additionally, there are no large-scale, quantitative assessments of the IRS's economic, social, and environmental impacts, which limits the ability to make evidence-based decisions. The lack of accountability mechanisms further exacerbates these issues, as stakeholders often fail to provide timely and accurate reports.

The presence of an outlier highlights variability in expert opinions, suggesting the need for stronger mechanisms to consolidate and apply evidence across regions, reducing fragmentation and improving consistency. Establishing centralized platforms for sharing knowledge and lessons learned could enhance the indicator's performance and more effectively support the scaling of the IRS system.

3.4.7 Technology and infrastructure

The indicator "Technology and infrastructure" reflects a mixed assessment regarding its readiness to support the scaling of the IRS system in the VMD (average score of 3.19). On the technology side, experts suggest that existing technological advancements are relatively sufficient. The rice-shrimp system has evolved over the past 50 to 60 years, with farmers in saline-affected areas adapting and refining the approach (Preston and Clayton, 2003). With accumulated experience over time, rearing techniques are no longer major challenges (Ngo, 2020). It has since been standardized into national-level training manuals by the National Agricultural Extension Center and widely disseminated across the country (NAEC, 2014). These materials provide detailed guidance on key aspects such as water management, crop and shrimp selection, disease control, and sustainable farming practices. The availability of these resources has facilitated the adoption of standardized practices, enhanced the efficiency and scalability of the IRS system, while ensuring that farmers have access to reliable technical support and best practices. However, further refinements are necessary to ensure the technique continues to evolve and align with the region's changing conditions, particularly in the context of climate change adaptation. Challenges such as salinity intrusion, altered rainfall patterns, and rising temperatures require advanced technical solutions, including salt-tolerant rice varieties, adaptive water management, and efficient resource use. Our findings align with ACIAR (2021), which also highlights these technical barriers and underscores the importance of participatory technology development. In addition, many farmers have yet to fully adhere to standard techniques, maintaining old farming habits according to the traditional farming practices, which may undermine the efficiency and sustainability of the system (Trinh, 2020).

Meanwhile, irrigation infrastructure remains a critical bottleneck, with an average score of only 2.68, highlighting significant limitations. Current irrigation systems, primarily designed for rice cultivation,

have been repurposed for the rice-shrimp model without significant modifications (Vu et al., 2023). This adaptation reveals critical limitations, as these systems struggle to effectively manage the dual requirements of retaining freshwater for rice while supplying saline water for shrimp. The conflict between saline and freshwater needs in transitioning areas has become a persistent challenge, often leading to inconsistent water management (Trinh, 2020). These shortcomings highlight the urgent need for infrastructure upgrades to enable flexible, dual-purpose water management, which is essential for the IRS system's scalability and sustainability.

On the contrary, the high score of 3.88 for the suitability of the IRS system with the existing field tilting in areas targeted for expansion reflects a strong alignment between the system's requirements and the current agricultural infrastructure. However, while this alignment is a positive factor for scaling, it also highlights the importance of localized planning to address potential variations in land conditions across different areas. Tailored interventions, such as minor adjustments to drainage systems or land preparation techniques, may still be necessary to maximize compatibility and productivity. Ensuring the system's adaptability to diverse field configurations will enhance its scalability and effectiveness.

3.4.8 Collaboration

The "Collaboration" indicator reveals moderate limitations in the capacity and readiness of stakeholders to work together effectively to scale the IRS system (average score of 3.16). Collaboration among key actors—such as banks, insurance companies, research institutions, and socio-political organizations—is essential for creating a supportive ecosystem. Additionally, collaboration at the regional and provincial levels plays an equally important role in ensuring cohesive efforts across the Mekong Delta. This is reflected in the score of 3.16 for *integrating existing initiatives*, highlighting a moderate ability to leverage resources from ongoing government programs, international projects, or private sector initiatives.

While some level of cooperation exists, the lack of motivation and binding mechanisms among these stakeholders reduces the potential for fully coordinated action (Rzepka et al., 2024). For example, banks and insurance companies often view shrimp farming as high-risk, limiting their interest in developing tailored financial products for the IRS system. Similarly, research institutions and socio-political organizations frequently face resource constraints and lack the institutional support necessary for long-term, cross-sectoral collaboration. Addressing these moderate but impactful challenges for improved collaboration, the IRS system can better utilize collective resources and expertise, enhancing its scalability and overall effectiveness.

3.4.9 Business case

The "Business Case" indicator reveals some challenges, with a relatively low average score of 3.03. Among all sub-indicators, *the accessibility of shrimp-rice products to high-value market segments* scores the highest at 3.69, indicating a favorable level of market penetration. These products meet stringent quality standards for high-end production, ensuring safety and strong economic returns. They hold considerable potential for establishing and enhancing regional brands or geographical indications (Trinh, 2020). However, market access remains limited in terms of quantity, for instance, while Vietnam's specialty and fragrant rice has begun penetrating

high-value markets, such as Europe and the Americas, transaction volumes remain small, averaging 2.36 thousand tons, and concentrated at 0.50 thousand tons (42%) over 2018–2020 (Dung et al., 2022).

A deeper examination reveals key barriers to establishing a robust business case. The *readiness and accessibility to market information*, with a low average score of 2.69, indicate that producers lack timely and actionable data for both input and output markets, hindering their ability to seize emerging opportunities. In the shrimp larvae market, inadequate information forces farmers to depend entirely on traders, resulting in low-quality, disease-prone larvae. Furthermore, the monopolistic control of prices and consumer markets by traders, coupled with shrimp's perishability and immediate consumption requirements, allows traders to dictate purchase prices, leaving farmers with limited bargaining power (Ngo, 2020). Fluctuations in market prices further exacerbate this issue, creating uncertainty and limiting farmers' ability to plan effectively (Vu et al., 2023). Moreover, producers often face challenges in understanding and meeting the specific requirements of high-value markets, including certifications, packaging standards, and traceability, which are increasingly demanded by consumers in Europe and the Americas. The quality of product outputs (i.e., rice and shrimp) still requires improvement to meet market standards and achieve higher prices (Dang, 2020).

Inadequate infrastructure for storage, logistics, and distribution further constrains producers' ability to scale their operations and access distant markets efficiently (Vu et al., 2023). *Brand development* also presents a critical area for improvement. With a score of 2.69, expert assessments indicate limited capacity for value addition and competitive brand positioning. Unlike rice products, with organic brands having been gradually built, shrimp products from the shrimp-rice farming models have not been branded and accepted by the market (Trinh, 2020). This reflects insufficient financial and technical resources and a lack of coordinated efforts to promote shrimp-rice products as premium goods with unique characteristics tied to their production regions. Developing strong regional brands and geographical indications could significantly enhance market appeal and create a competitive edge, but this requires substantial investment in branding, marketing, and capacity building.

3.4.10 Finance

The "Finance" indicator reflects significant challenges, with the second-lowest average score of 2.8, highlighting systemic issues in accessing and managing financial resources to scale the IRS system. Among the sub-indicators, the *financial capacity of farmers* to transition to the IRS system, considering both initial and recurring costs relative to their average income, scored moderately at 3.25. While some farmers demonstrate financial preparedness, others face significant limitations that hinder broader adoption of the system. Access to financial services such as savings, credit, payments, and insurance is therefore critical to enabling farmers to diversify their investments and adopt innovations (Ngoc et al., 2016; Nguyen et al., 2017; Brown et al., 2018).

However, current financial mechanisms remain poorly suited to the needs of the IRS value chain, as reflected in the low score of 2.75 for *readiness and suitability of financial plans and mechanisms for mobilizing public and private resources*. Limited institutional and policy support exacerbates this issue, leaving many farmers with inadequate access to finance, particularly to cover transformation

costs or address challenges caused by irregular weather patterns exacerbated by climate change (Dung et al., 2017). Key barriers include high transaction costs for small loans and savings, insufficient collateral, and the high risks associated with farming due to drought, salinity intrusion, and floods. The lack of policies facilitating financial service coverage further limits farmers' options (Khandker, 2021).

As a result, many farmers rely on informal credit sources, such as loans from friends and relatives, to avoid constraints associated with formal credit lines. These constraints include administratively burdensome processes, collateral requirements, and unsuitable loan sizes, all of which create additional risks and challenges (Khoi et al., 2013). Furthermore, *the ability to respond to financial risks* within the IRS value chain scored even lower at 2.44, underscoring a critical weakness in financial resilience among stakeholders.

3.4.11 Value chain

The "Value chain" indicator highlights significant structural and organizational challenges, reflected by the lowest average score of 2.5 among all evaluated indicators. A key issue is *the fragmented and small-scale nature of production in the IRS system*, with a very low average score of 0.69. This lack of large, consolidated production zones complicates the collection and aggregation of products, limiting the ability to meet market demands efficiently. Secondary data supports this observation, showing that over 80% of farming households in the VMD operate on less than 2 hectares of land (GSO, 2021), which significantly constrains economies of scale and increases transaction costs for buyers. Another critical barrier lies in the *weak collective organization of farmers*, with an average score of 2.75. The current state of cooperatives and farmer organizations in the VMD is underdeveloped. According to recent statistics, as of June 2024, the VMD had 21 cooperative unions and 2,774 agricultural cooperatives, representing 13% of the total agricultural cooperatives nationwide, with only more than 2% of households participating in these cooperatives (Huy, 2024). Many existing cooperatives lack the resources and management capacity to support value chain activities effectively (Trinh, 2020; Hua and Brown, 2024). This organizational weakness exacerbates challenges in coordinating production, ensuring quality standards, and negotiating better terms with buyers.

Additionally, issues of transparency and profit-sharing within the value chain remain major obstacles. The indicator for *fairness and transparency in sharing profits among stakeholders* scored an average of 2.63, reflecting dissatisfaction with how value is distributed across the chain. This is the common issue of agricultural and aquacultural value chains in the VMD, where farmers often have a high contribution of net added value but a limited share of profit and income (Loc et al., 2021). Similarly, *linkages, commitments, and collaboration among stakeholders* also scored low at 2.63, highlighting the weak relationships between producers, processors, and traders. While some enterprises have begun forming partnerships with shrimp-rice production groups and cooperatives, these efforts are largely limited to providing inputs such as rice varieties and purchasing rice at slightly higher rates than the market. Despite these initiatives, there is no well-defined risk-sharing mechanism or price guarantee system to mitigate challenges such as 'big crop–low price,' leaving collaborative efforts fragmented and insufficient (Trinh, 2020). Without stronger partnerships and equitable profit distribution, mistrust among stakeholders is likely to persist, hindering efforts to scale the IRS system effectively.

4 Conclusion

Our integrated assessment of the IRS system highlights its significant potential for scaling up, albeit with varying levels of readiness across different locations. Climate change emerges as the most influential external factor, yet the system retains considerable natural adaptability, providing opportunities for expansion. The environmental benefits of the rice-shrimp model are evident, while its economic contributions primarily focus on ensuring more sustainable livelihoods. However, the social impacts remain less clear. Overall, the findings confirm the feasibility of scaling up the IRS system in the VMD, provided key conditions are addressed and necessary capacities are strengthened.

In terms of the enabling environment, there are strong institutional conditions and local commitments to support the adoption and scaling of the IRS system in the VMD as a potential measure to adapt to and mitigate the effects of global climate change and sustain the livelihoods of coastal areas affected by saline intrusion. Additionally, a relatively comprehensive body of technical and economic data is available to inform the model's expansion. However, several challenges hinder the system's broader implementation, including limited financial capacity, fragmented small-scale operations, and the weak role of farmer organizations. Market access and brand development remain underdeveloped, while transparency and efficiency in the value chain are lacking. Furthermore, irrigation infrastructure is inadequately synchronized to support the dual requirements of rice and aquaculture production.

Several policy actions are recommended to address these challenges and realize the full potential of the IRS system. Financial support mechanisms, such as providing loans and covering certification costs, should be implemented to encourage enterprises to collaborate with farmers and secure market linkages. Farmers should be reorganized into groups, cooperatives, and associations to enhance production integration and amplify the role of social organizations in supporting these efforts.

Clear and transparent development plans tailored to local conditions should be approved, focusing on identifying areas suitable for organic rice-shrimp cultivation. Investments in synchronized transportation and irrigation infrastructure are crucial for supporting ISR farming on a larger scale. Policies that strengthen value chain linkages should also be prioritized to attract private sector investment, foster benefit-sharing, and establish exemplary value chain models for broader adoption.

Additionally, developing and standardizing technical guidelines and regulatory frameworks for the IRS system is essential. This includes specifying best practices for stocking density, seed selection, and other production parameters. Branding and identification systems for rice-shrimp products should be created to improve market recognition and competitiveness.

Finally, diversifying production models can enhance the system's resilience and productivity. This could include incorporating additional aquaculture species, such as crabs and fish, and combining these with vegetable cultivation on dikes. Such diversification would increase productivity, strengthen farmers' livelihoods, and contribute to the overall sustainability of the system.

The findings of this study present a critical review of the available literature and the results of an expert consultation

workshop. As such, it is unable to cover the diverse perspectives of stakeholders working on IRS systems in the VMD at the delta scale. Future studies could expand study samples or adopt the scaling readiness and scanning scan tools in full scale to provide further insights on the dynamics of the conditions for scaling the IRS system in the VMD. Triangulating stakeholder scoring results with quantitative indicator-or metric-based assessments of IRS systems could provide further insights into understanding the dynamics of IRS system scaling. Finally, follow-up studies investigating the biophysical potential and suitability of IRS systems are crucial for a comprehensive understanding of the ISR potential and its scaling dynamics.

Data availability statement

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

Author contributions

NT: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing, Visualization. KD: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. LL: Data curation, Formal analysis, Investigation, Writing – review & editing. TD: Data curation, Formal analysis, Investigation, Writing – review & editing. DN: Data curation, Formal analysis, Investigation, Writing – review & editing. TP: Data curation, Investigation, Writing – review & editing. DL: Writing – review & editing. MA: Writing – review & editing.

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Conflict of interest

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

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