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SHORT COMMUNICATION

A stakeholder perception and SWOT analysis of seaweed cultivation in Kemujan Island, Indonesia

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Abstract Some coastal communities depend on seaweed farming to meet daily needs. The study incorporates seaweed farming into the marine protected zones. The study was conducted in Kemujan Island in April 2026, followed by a search for farmers in their hamlets because it is the center of seaweed farming in the Karimunjawa National Park. Key parameters included a SWOT analysis, stakeholder perceptions, general socio-economic information, and conservation attitudes, collected from 50 participants across three sites: Beach Mrican, Beach Telaga, and Beach Batulawang. The findings showed that 78% of the participants depend on seaweed as their primary activity. 94% reported no destruction of mangroves and coral reefs, whereas 96% documented that there was no formal permission for the establishment of a farm. The SWOT model used weighted scores. On the strengths side, good-quality seedlings scored 12.98, followed by natural water quality at 12.20. The major weaknesses were seed degradation and limited processing technology, with scores of 11.06 and 11.32, respectively. In the opportunity parameters, market expansion and government support had weight scores of 13.54 and 13.47, respectively, and the highest threats were disease (ice ice) 11.94 and climate change (warming water) 10.88. Participants emphasized the seed laboratory 52% over the better jetty 36% and processing plant 12%. Finally, farmers prioritized strong permits, seed-quality infrastructure, and a wider range of market alternatives as key factors to maximize production.

Keywords Kemujan Island . Seaweed farming . Marine protected areas . SWOT analysis . Stakeholder perception

Introduction

Seaweed cultivation produces over 36 million tons (wet weight) each year and exceeds a global market worth USD 16.5 billion (FAO 2022). Indonesia is the second-largest seaweed producer, accounting for around 28% of global production, mainly from cultivating *Eucheuma cottonii* and *Gracilaria* species (Valderrama et al. 2015; FAO 2022). The seaweed farming activity supports the livelihoods of approximately 300,000 cultivator families and enhances coastal ecosystem services, such as habitat provision, carbon sequestration, and nutrient cycling (Froehlich et al. 2019).

Karimunjawa National Park (KNP) was established in 1982 and designated a UNESCO Biosphere Reserve and a marine protected area (MPA) in Indonesia. Kemujan Island is home to a seaweed-cultivation community that has farmed seaweed for many years (Azzahra et al. 2023). The connection between seaweed cultivation and the national park authority, including licensing restrictions, zoning constraints, and environmental protection requirements, creates a difficult socio-ecological scenario that requires structured evaluation (Skapste et al. 2025).

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In Kemujan, seaweed farmers still facing multiple challenges, such as the degradation of seeds through continuous vegetative propagation, the absence of infrastructure for post-harvest drying and processing, high transportation costs to reach the Jepara market on the mainland, and price fluctuations caused by speculation through networks of collectors (Beattie et al. 2026). Meanwhile, a blue carbon credit market is inspiring many global emerging opportunities through eco-tourism integration and a large increase in the carrageenan market, as illustrated by panels that develop solutions when managed correctly (Rebours et al. 2014; Duarte et al. 2022).

Integrated institutional, socio-economic, and perceptual analyses of seaweed farming to advance blue economy potential in Indonesian MPAs remain scarce (Sutrisno et al. 2024). SWOT analysis provides a strong participatory model for closing this gap when paired with cross-stakeholder perception surveys (Teece 2018).

The survey's objectives include (i) assessing the sociodemographic profile of the farmer, (ii)evaluating stakeholder perceptions of the conservation between coral reef ecosystems and seaweed cultivators, (iii) assessing the institutional and regulatory model governing seaweed farming, (iv) measuring SWOT factors using a weighted rating approach, and (v) recognizing strategic investment priorities for the sustainable development of the sector.

Materials and methods

Study area

The study was carried out on Kemujan Island, Karimunjawa National Park in Jepara Regency, Central Java, Indonesia, 5°52'S, 110°28'E (Figure 1). The number of seaweed farmers in Kemujan Island is below 200; the 50 participants represent more than 30% of the population, and the researcher included them in the study, distributed across three coastal settlements: Beach Mrican, Beach Batulawang, and Beach Telaga. All three cultivation zones use the long-line technique because water depth ranges from 2m to 8m, and *Kappaphycus alvarezii* and *Eucheuma dentriculatum* are the primary seaweed species planted. For example, South Sulawesi and Madagascar increasingly cultivate long-line *Kappaphycus alvarezii*, with growth rates of about 5.1% per day, reflecting rapid growth and boosting economic benefits (Ateweberhan et al. 2015; Rama et al. 2018). Seaweed farming faces challenges from high temperatures, wave action, and sediment, arising from both natural and anthropogenic sources (Kennedy et al. 2020).

Data collection

In April 2026, 50 purposefully chosen seaweed farmers were interviewed regarding socio-demographic data, institutional and regulatory framework, stakeholder perceptions and conservation, SWOT factors, and

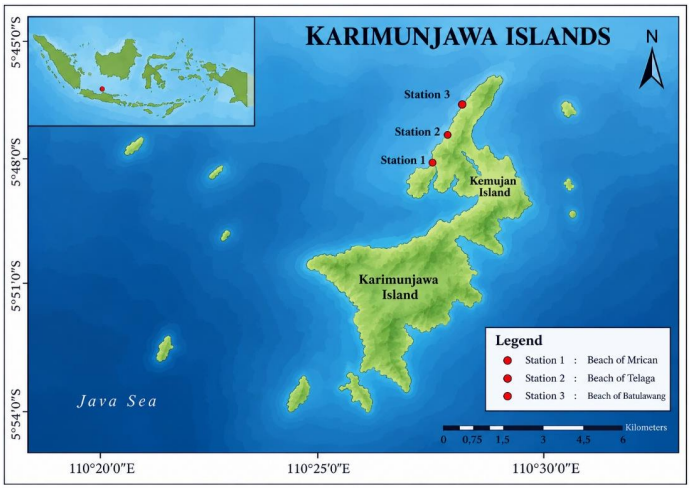


Fig. 1 Research location

strategic priorities, due to the limitation of the farmers in the sites to operate random sampling. SWOT factors were analyzed and calculated using a four-point Likert mean rating scale (1 = Strongly Disagree, 4 = Strongly Agree) combined with an importance mean weight scale (1 = Not Important, 4 = Very Important) for 20 factors across four SWOT categories. WS values are comparable among factors but are not percentages or probabilities. WS was used to rank factors within and across SWOT categories. For each factor, respondents indicated their level of agreement with a statement describing the factor (rating, R) and rated how important the factor was (importance weight, W). Both scores reflect participants' self-reported opinions, judgments, and perceptions. Each of the three coastal communities provided about equal numbers of respondents (17, 17, and 16, respectively). These methods are linked to the study carried out in Malaysia, which incorporates seven communities through focus group discussions, household surveys, and interviews, using a mixed-methods approach to capture both industrial and community perceptions (Nor et al. 2017).

Data analysis

The 20 SWOT criteria were used to examine the two mean important weights and rating scores. A composite weighted score ($WS = \bar{R} \times \bar{W}$) was created by the product of the mean rating and mean weight. This score provides a single metric that accounts for both the perceived magnitude and the strategic significance of each aspect (Rizki et al. 2021). The descriptive statistics, including means, frequencies, percentages, and standard deviations were applied. Furthermore, according to Kangas et al. (2001), SWOT factors can be quantified using AHP-derived weights, thereby enabling the calculation of priorities and rankings for decision-making. The SWOT analysis currently integrates quantitative measurements with stakeholders' perceptions to provide sufficient and clear information for strategy formulation (Vlados and Chatzinikolaou 2019).

Results

Socio-demographic Profile

The study included 50 participants: 23 men and 27 women (46% and 54%, respectively (Figure 2a), with a mean age of 48.6 years (SD = 12.3). Participants ranged in age from 27 to 80 (Figure 2b). The three most common ethnic groups, Bugis (56%), Javanese (32%), and Madurese (12%) (Figure 2c), reflect the historical patterns of seaweed production from South Sulawesi to Karimunjawa.

78% of respondents reported that seaweed cultivation was their primary source of income; the oth-

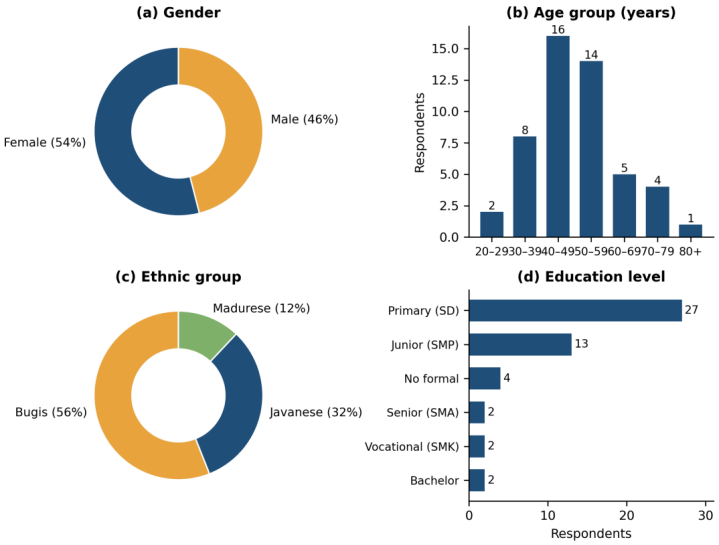


Fig. 2 Socio-demographic profile of participants: (a) gender distribution, (b) age distribution, (c) ethnic group distribution, and (d) education level.

ers worked in homestay businesses (4%), fishing (10%), or other service-related jobs. Most respondents' secondary income source was fishing (26%), followed by small-scale trading. In terms of education, 4% reported having a bachelor's degree, 26% junior secondary school (SMP), and 54% had completed only primary school (SD) (Figure 2d). The adoption of technology and value chain enhancement was significantly impacted by this profile of low educational attainment.

Institutional and regulatory framework

Three major concerns related to the regulatory environment were examined in the study. First, the KNP zoning system provides a real spatial boundary for production areas. 60% of participants reported that the current zoning was partially supportive because it reduces spatial conflict among fishing, seaweed farming, and tourism activities. 36% reported that appointing prior cultivation areas as protected zones prevented expansion in Karimunjawa National Park (KNP).

Second, 96% of participants agreed that the licensing procedure for using the seaweed plot was unstructured and decentralized, and was determined solely by simple consensus. The farmer reported that the current situation showed that formal permission was not followed and that decisions were made only verbally by cooperative heads or village leadership. Although this reduced administrative power, it also increased landholding instability and made it harder to obtain government support and income.

Third, a community organization performed certain responsibilities for seaweed cultivators on behalf of the government, but only in rare cases, not on a regular schedule. 48% mentioned support modalities included knowledge and skills in farming practices; 68% regarded seed delivery as an important aspect; and 54% reported supplying equipment, including ropes and cultivation equipment. Significantly, only two participants identified specific restrictions to preserve water quality, indicating that cultivation sites lacked environmental safeguards.

Stakeholder perceptions of conservation synergy

94% of participants perceived that seaweed cultivation does not affect coral reefs. They explained that cultivation lines were placed far from coral reef habitats; seaweed farming occurs in the marine culture zone, far from coral reefs. Meanwhile, 30% of participants reported that seaweed cultivation was robust and actively protective, arguing that the availability of farming infrastructure hinders harmful fishing methods. Only one participant recorded a prior misunderstanding with fishermen concerning the geographical overlap of cultivation lines and nets, and no one illustrated any incidents that occurred from tourism activities.

Participants reported that farmers actually follow best management practices to conserve the coastal environment. They documented no mangrove cutting, farming far from coral reef habitats, and proper waste disposal, such as unused raffia and plastic bottles. On the other hand, participants described future support based on institutional commitment to funding or advocating for seaweed-related infrastructure over the next 5 years; 76% rated it very large or large. However, this prediction decreased with multiple responses about government involvement, especially in providing necessary tools, subsidies, and materials for seaweed farmers.

SWOT analysis

In the strength parameter, good-quality seedlings had the highest weighted score (WS = 12.98), followed by natural water quality (12.20) and appropriate farming techniques (12.12) (Figure 3). The participants recognized the unique natural growing conditions of KNP waters, including temperature, water clarity, salinity, and current patterns, as essential resources for producing high-quality seaweed. Existing cooperatives reported the lowest strength 10.76, reflecting views that cooperative governance is insufficient and that cooperative membership does not substantially improve market access or input procurement.

In the weakness parameter, the highest weighted scores were high logistics costs to Jepara WS (11.64), limited processing technology (11.32), and seed degradation (11.06). Raw seaweed was transported across different locations in Java for marketing through small industries; this system drives price fluctuations, especially for farmers. The two consecutive parameters with the lowest weighted scores were poor drying

techniques (9.90) and low productivity per line (9.80), as illustrated in Figure 3.

The opportunities section had the highest weighted score among the four parameters, with market ex-

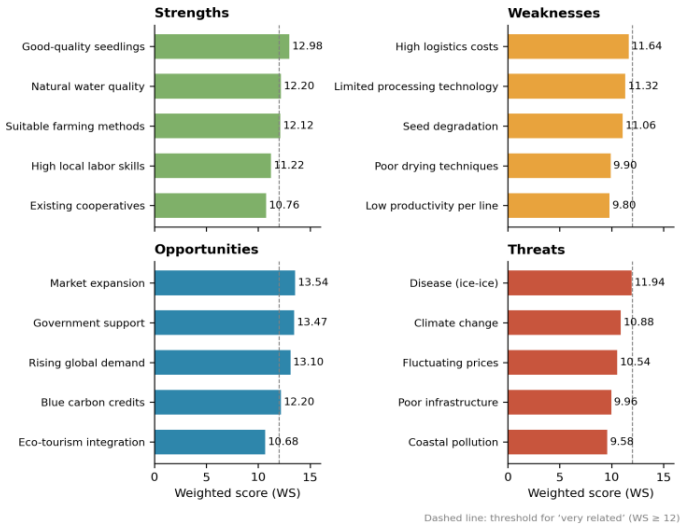


Fig. 3 Weighted scores (WS) of the 20 swot factors for seaweed farming on kemujan island (dashed line marks the "very related" threshold (WS ≥ 12).

Table 1 Proposed strategies for SWOT factors and their combined factors

Strategy	Proposed action	Factors combined
SO1	Integrating farming methods, labor skills, and quality seedlings tends to increase production and expand both global and domestic markets.	S1, S2, S3, S4, S5; O1, O5.
SO2	Using local skills and suitable farming methods, it enhances ecotourism activities to strengthen seaweed farming and cooperative business.	S1, S2, S3; O1, O2.
SO3	Improve cooperatives' access to government support, channels, and diverse marketing.	S2; O1, O2.
SO4	Suitable farming practices linked to existing cooperatives increase opportunities for environmental investment and other carbon benefits.	S1, S2, S4; O4
WO1	Frequent training and government support improve per-line productivity through best strategies, drying techniques, and seed quality.	W1, W2, W5; O2, O3.
WO2	Dealing with drying and processing technology, farmers can produce high-quality seedlings to expand markets.	W4, W5; O1.
WO3	Involving various cooperatives and sharing logistics help reduce transport costs and improve access to the best markets.	W3, W4, W5; O1, O5.
WO4	Reduce dependence on selling raw seaweed directly by promoting ecotourism practices and a variety of seaweed products.	W1, W2; O1, O2.
ST1	Using local skills and suitable farming methods improves farm management and minimizes climate and disease impacts.	S1, S3; T3, T5.
ST2	Using suitable farming practices and good quality seedlings strengthens crop resilience and minimizes losses derived from ice-ice disease.	S1, S5; T1, T3
ST3	The diverse cooperatives improve production, market information, shared transport, and information related to price fluctuations and poor infrastructure.	S2; T1, T4.
ST4	By practicing best farming methods and maintaining natural water quality, minimize coastal pollution and protect farming sites.	S1, S4; T1, T2
WT1	Strengthen farm and seed productivity to minimize climate and disease outbreaks.	W1, W2; T3, T5.
WT2	Improve essential processing practices and drying techniques to eliminate post-harvest losses and maintain seaweed quality despite logistical constraints.	W4, W5; T2, T5.
WT3	Use the best marketing arrangements, storage, and an effective assigned transport pathway to manage maximum logistics costs, fluctuating prices, and poor infrastructure.	W3; T1, T4.
WT4	Initiate practical farm monitoring and evaluation, and regularly measure ice-ice disease, climate-related problems, and coastal pollution.	W1, W2, W5; T2, T3, T5

Note: S = Strength, W = Weakness, O = Opportunity, T = Threat. Numbers follow the factor order in Fig. 3. Strategies are interpretive proposals based on perception scores.

pansion scoring highest (13.54), followed by government support (13.47) and rising global demand for carrageenan (13.10) (Figure 3). The next item that received intermediate scores was blue carbon credits 12.20. The last parameter with the lowest weight score was eco-tourism integration (10.68), because the interaction between tourism and cultivation sites was reported as null.

In threat factors, the maximum weight score was ice-ice disease 11.94. The next threat factors were climate change, fluctuating local prices, coastal pollution, and poor infrastructure, which reported weighted scores of 10.88, 10.54, 9.58, and 9.96, respectively, as shown in Figure 3.

The strategies in Table 1 were formulated by combining the highest-scoring SWOT factors (SO, WO, ST, and WT pairings). Based on the proposed alternative strategies from the SWOT factors, the farmers provide the current situation based on the weighted score for each category.

Strategic Investment Priorities

The infrastructure priorities were reported differently based on farmers perspective, 52% reported having a laboratory for seed quality, 36% reported a better jetty, and only 12% reported a processing plant (Figure 4). The availability of a maximum response in the seed quality laboratory shows that seed is the most important and comprehensive factor in starting or maintaining cultivation; on the other hand, seed deterioration lowers overall production. The improvement of Legon Bajak port in Kemujan marked an important development that facilitates the simple loading and unloading of goods and services and increased the value of cultivated seaweed.

Discussion

The seaweed sector in Kemujan Island shows a strong commitment to human and natural capital through opportunities and strengths in the SWOT analysis; however, it can be hindered by a poor sector model that converts ecological capacity into financial value and by insufficient supply chain materials, particularly substantial threats and weaknesses (Suryanti et al. 2025).

The weight score of 12.98 in good-quality seedlings is directly related to evidence reported by Aeni et al. (2019), indicating that seaweed seed from Sulawesi, especially cottonii farming in Karimunjawa National Park, yields the highest carrageenan product compared with other seed-producing in areas of Karimunjawa. The 52% result related to seed laboratory establishment suggests that farmers perceived it as a possible way to increase income and support development progress; however, the actual income effect was not quantified (Sundareswaran et al. 2023).

The findings indicate that strategies supported by overseas market access are more effective than other methods of institutional production. Seaweed farmers in developing countries prioritize sector collaboration over market reform as an important pathway to institutional improvement (Valderrama et al. 2015; Porse and Rudolph 2017). The lower result on eco-tourism integration suggests that changing, broadening, and engaging in tourism activities, such as care, assistance, and accommodation, along with multilingual speakers, requires a budget, making it hard for many cultivators to practice this activity.

Respondents consider Kemujan's general environment well protected, which aligns with the World site's

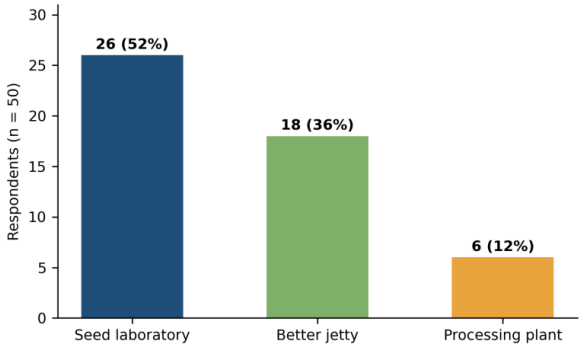


Fig. 4 Respondents' priority for infrastructure investment

perspective on protecting the marine environment. Although connected to environmental factors, this requires strong evidence from ecological data such as sedimentation conditions near the farming area, water quality assessments, and overall reef condition (Uthicke et al. 2010). Partnership, monitoring, and evaluation support seaweed environmental conservation if the community considers it (Frey and Berkes 2014). Notably, to enter new markets and strengthen finances, it focused more on efficient ways to promote the life category in seaweed activities that are consistent with preservation (Rasowo et al. 2024).

The temperature of the Java Ocean is projected to increase gradually from 0.5°C to 1.0°C by 2050, increasing susceptibility to ice-ice disease in seaweed (Solomon 2007). The proposed method to minimize this disease was to establish a seed laboratory to ensure a consistent supply of seaweed seed (Tahiluddin and Terzi 2024). Lack of formal permission to start seaweed farming was associated with unsustainable ocean use, reduced village government income, disobedience to the seaweed organization's rules and principles, and slower production (Leslie et al. 2015). By addressing these issues, Karimunjawa National Park Authority uses local wisdom to gain local community support, lower availability limits, and maintain the current plan, derived from Indonesian marine protected areas under the Coral Reef Rehabilitation and Management Program-Coral Triangle Initiative program (Zamroni et al. 2020).

Farmers perceived that infrastructure availability plays a significant role in boosting development and improving quality of life in the cultivation sector. For example, good, modern jetties that enable efficient loading and unloading of goods and services improve access to better markets and help minimize logistical barriers (Tullberg et al. 2022). For example, in Tanzania, small seaweed farmers faced technical infrastructure constraints and difficulty reaching better markets, and cultivators' economic status remains low. Farmers saw investing in laboratory construction as a way to achieve greater production stability and continue strengthening (Charisiadou et al. 2022; Matoju et al. 2022).

Respondents described reducing pressure on fishing and coral reef habitats and populations, aligning with conservation measures for marine activities (Kelly et al. 2020). Farmers practicing on sandy areas rather than directly on coral reefs reduce direct interaction between seaweed farmers and coral reefs, as farmers described. Riniwati et al. (2019) suggested that isolating fisheries and seaweed farmers reduces conflict and destruction of cultivation, and that adequate local government zoning can reduce misunderstandings.

Combining different strengths and opportunities expands seaweed farming. This model reported to enhance ecosystem services and management to increase cultivation production similarly related to the environmental targets and market accessibility (Sen et al. 2026). The weakness-opportunity strategy aims to turn the problem into a benefit. Frequent training, skills building, and quality seed production align with capacity building and technology advancement that may improve production (Kimanga et al. 2025).

Farming methods techniques and labor training skills reported to reduce the effects of threats. The situation conveys environmental monitoring, disease management, and best farming practices to support more stable production under any environmental situation (Corr et al. 2026). The weakness-threat model is perceived as the best and most practical solution, as the integration signifies clear changes. The transportation solution regarded as an assistant to run the process smoothly as the market obtained in effective ways and improves the living standard of the farmers (Sutrisno et al. 2024).

Conclusions and management implications

This study was the first attempt to describe stakeholders' perceptions of seaweed farming and to conduct a SWOT analysis in Kemujan Island. The overall SWOT parameters provide the opinions of farmers towards the farming environment. Farmers reported that farming was conducted acceptably; production varied by farmer, indicating that some farmers cultivate seaweed as their primary livelihood despite challenges. The study's strategies, derived from the SWOT results, aim to make the seaweed sector viable, achievable, and meaningful for farmers and other stakeholders. Finally, the author provided recommendations based on the findings to make seaweed cultivation active, well-organized, and a sustainable, independent sector for the future, and to reduce the difficulty of seaweed operations. First, improve Legon Bajak port to ensure effective, smooth transportation of raw seaweed, as 36% of farmers reported high logistics costs to Jepara. Second, build a consistent-quality seed laboratory across all three zones to reduce the burden of transporting seed over long distances and replace damaged seed with new seed, which 52% cited as an infrastructure

priority and rated highly for good-quality seedlings, seed degradation, and ice-ice disease. Third, provide special permission for ocean use to promote proper use of the ocean environment and maximize local government income, with 96% reporting no formal permission. Fourth, regulate price fluctuations; fair prices are needed because the work requires significant effort and energy, and the price fluctuation score of 10.54 supports this. Fifth, to reach better markets, the seaweed selling system should diversify its selling stations, as 100% of farmers currently sell their seaweed only to collectors. Last, verifying perceived environmental effects through simple ecological monitoring near farm sites, such as reef condition and water quality, would allow the farmers' perceptions to be checked with data.

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Conflict of Interest The authors declare that there is no conflict of interest.

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