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Socio and Spatial Economic of *Kappaphycus alvarezii* Cultivation in South Sulawesi, Indonesia

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ABSTRACT

Seaweed has the potential to become a significant fisheries commodity in the coastal areas of Bone Regency. This study aimed to analyze the socioeconomic aspects of seaweed cultivation in Bone Regency as part of a strategy for its sustainable management. The research was conducted in three villages known for their seaweed production: Palette Village, Mallari Village, and Waetuwo Village. Data were collected using purposive sampling techniques, including observation and interviews with 90 seaweed farmers. Socioeconomic data were analyzed using percentage and SWOT analysis, while spatial analysis was used to examine the distribution of respondents and cultivation locations. The results showed that seaweed management strategies in Bone Regency fall within quadrant 1 of the SO (Strengths-Opportunities) strategy. This strategy focuses on increasing community involvement in government programs that support the development of seaweed as a key commodity, leveraging local knowledge and experience. The recommendations include developing training and education programs to improve cultivation skills, enhance productivity, and raise the quality of seaweed products to meet growing demand. Additionally, optimizing local and national marketing networks, implementing digital marketing strategies, and expanding access to international markets are essential. Finally, encouraging younger farmers to utilize land more effectively, in line with RZWP3K (spatial planning regulations), could increase the area available for seaweed cultivation.

INTRODUCTION

Indonesia plays a crucial role in the global seaweed market **(Muflikh *et al*., 2024)**. It is the second largest seaweed producer in the world after China and is a significant producer of red seaweed, especially *eucheumatoid*, *Kappaphycus*, and *Eucheuma* species **(Cai *et al*., 2021)**. Seaweed farming is a suitable alternative livelihood for coastal communities and can improve the socio-economic conditions of the farmer's family. This cultivation's success provides economic benefits and contributes to environmental conservation and community welfare **(Larson *et al*., 2021)**. *K. alvarezii* has rapid growth characteristics and can produce harvests quickly **(Rimmer *et al*., 2021)**. With increasing human needs, the utilization of marine resources has become a significant focus in the field of sustainable economic development **(Rimmer *et al*., 2021)**.

South Sulawesi is the largest province producing seaweed in Indonesia. *K. alvarezii* seaweed is the leading commercial species cultivated around Sulawesi **(Adhawati *et al*., 2024)**. Bone district is the third largest administrative district in South Sulawesi, after North Luwu and East Luwu districts, with an area of 4,567.363km² and 138km of coastline. Bone Regency is one of the leading seaweed producers in South Sulawesi, with the species *K. alvarezii* being the most widely cultivated. Seaweed production in the Bone Regency will reach 222,168 tons by 2023 **(BPS, 2024)**, indicating the considerable seaweed potential in this area.

With the development of seaweed aquaculture, challenges such as market price fluctuations, limited market access, and pest and disease attacks have emerged. In addition, the lack of community knowledge about zoning or spatial planning for aquaculture activities is also an obstacle that can affect income and business sustainability. A better management strategy is needed to utilize seaweed aquaculture economically and socially **(Hasselstrom *et al*., 2020)**. This requires the development of management policies **(Rimmer *et al*., 2021; Farid *et al*., 2024)**. Therefore, an effective and sustainable management strategy is essential. One approach that can be applied is a spatial-based strategy **(Andrefouet *et al*., 2021)**, which uses spatial information systems for seaweed aquaculture management. This approach allows for more accurate and efficient zoning and potential cultivation areas **(Tasnim *et al*., 2024)**.

This study is a comprehensive analysis of the socio-economic aspects of seaweed aquaculture in Bone Regency. It aimed to develop spatially-based management strategies that will support the sustainability of this sector. By taking a holistic approach, we expect to provide a robust set of recommendations for the development of seaweed aquaculture that is efficient, sustainable, and maximizes benefits for local communities and the regional economy.

MATERIALS AND METHODS

Research time and location

This research was conducted in April-July 2024 in the coastal area of Bone Regency, which includes three villages, namely Palette Village, Mallari Village, and Waetuwo Village, and two sub-districts, namely Tanette Riattang Timur Sub-district and Awangpone Sub-district. These areas were chosen because they are the center of seaweed cultivation in Bone Regency, which has the highest production. The research location map is presented in Fig. (1).

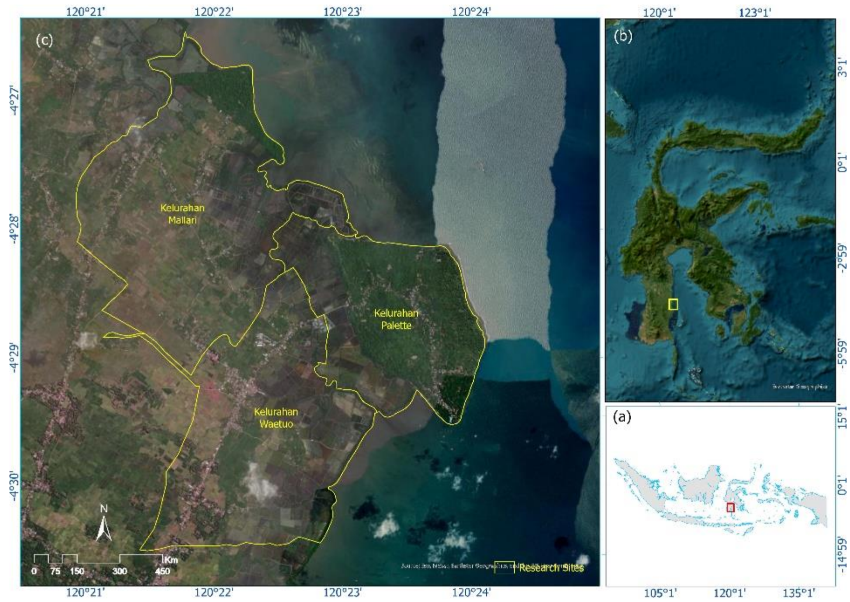

Fig. 1. Research location map

Data collection

The research data were obtained through observation, field surveys, and literature studies. Questionnaires and interviews were used to collect quantitative and qualitative data **(Ahmed *et al*., 2022)**. The questionnaire included general information on seaweed farmers: age, experience, number of dependents, farm size, and geographical coordinates of home and farm location. The questionnaire also covered socio-economic conditions such as land ownership, labor, cultivation methods, production quantities, prices, and marketing. Samples were taken using a purposive sampling method based on the following criteria: seaweed cultivation as the main livelihood, cultivation location in marine waters, and type of seaweed *K. alvarezii*. If the sample population was less than or equal to 1,000, the entire population was taken (census). If the population is more than 1,000, 10% is sampled **(Sugiyono, 2015)**. In this study, the census method was used, so the sample population consisted of 90 seaweed farmers, divided into 30 respondents in Palette Village, 30 in Mallari Village, and 30 in Waetuwo Village.

Data analysis method

Data on the distribution of respondents and seaweed cultivation locations were analyzed using spatial analysis. This involved combining interview data with respondents' attributes and cultivation location data to visualize the spatial distribution of both respondents and cultivation sites. The resulting analysis was then overlaid with the Zoning Plan for Coastal Areas and Small Islands (RZWP3K) of South Sulawesi Province, specifically focusing on marine space utilization zones. The result of spatial analysis is a map of recommended locations for seaweed aquaculture development. Meanwhile, socioeconomic data were analyzed descriptively in tables, and conventional percentages were used to assess the socioeconomic status of seaweed farmers using percentage analysis.

To determine management strategies for seaweed aquaculture, a SWOT analysis was used. This analysis examines various components in a structured way to formulate a strategy. The resulting strategy is determined by maximizing strengths and opportunities and minimizing weaknesses and threats. Strategic decision-making is usually related to the objectives and policies of the activity. In strategic planning, SWOT analysis assesses strategic components such as strengths, weaknesses, opportunities, and threats under existing conditions **(Abdel-Hady *et al*., 2024)**.

The internal factors evaluation (IFE) and external factors evaluation (EFE) tables were determined by calculating the weight and rating values of the internal factors **(Rangkuti, 2016)**. The weight of each factor in the analysis was assigned based on responses to questions asked of the respondents. Weights ranged from 1.0 (most important) to 0.0 (not important), reflecting the factor's impact on the strategic position of seaweed farming. Ratings were assigned on a scale from 4 (outstanding) to 1 (poor), indicating the performance of each factor.

RESULTS AND DISCUSSION

Distribution of respondents and location of seaweed cultivation

The distribution of seaweed cultivation respondents in Palette, Mallari, and Waetuwo villages is the center of seaweed cultivation in Bone Regency, which has the highest production. The respondents' distribution and the seaweed cultivation location can be seen in Fig. (2).

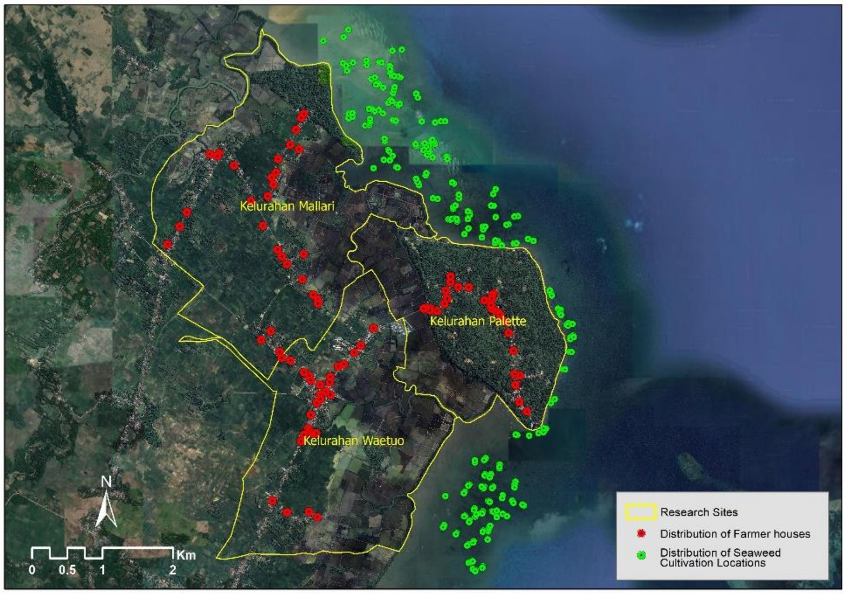

Fig. 2. Map of respondent distribution and seaweed cultivation locations

General conditions of seaweed farmers

The characteristics of seaweed farmers in Bone Regency, by explaining some general aspects of seaweed farmers such as age, education, cultivation experience, and number of family dependents, are presented in Fig. (3).

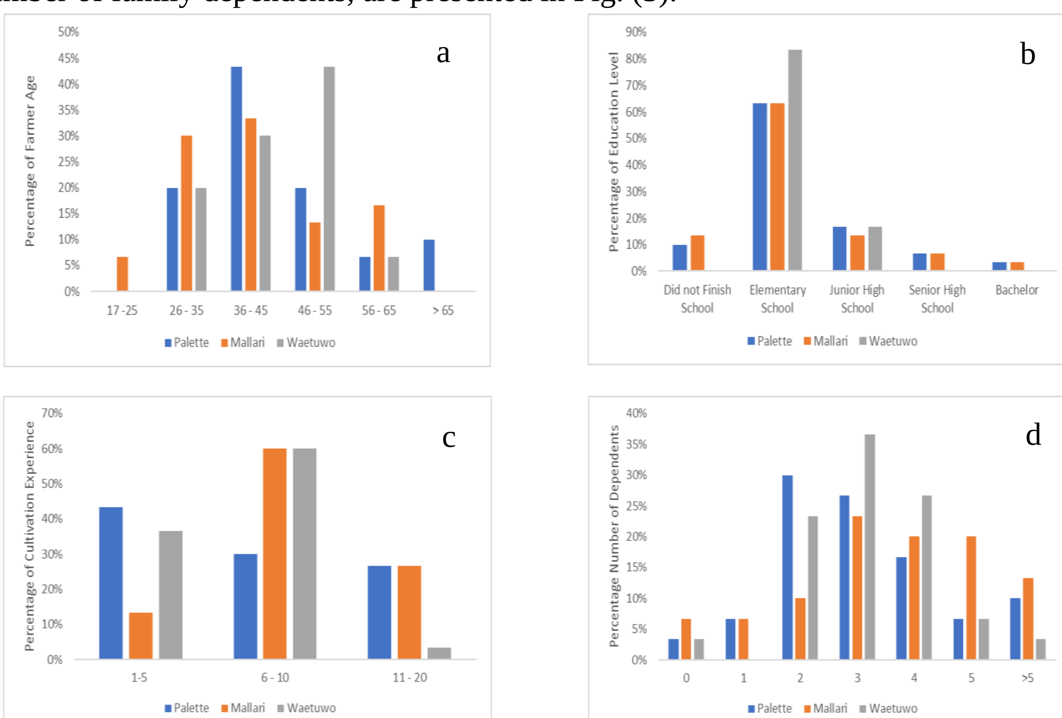

Fig. 3. General characteristics of seaweed farmers in Bone Regency. a. Farmer age, b. Education level, c. Cultivation experience, d. Number of dependents

The characteristics of seaweed farmers in Bone Regency who became respondents in this study ranged in age from 22 to more than 65 years, with the majority being in the range of 36 to 45 years (Fig. 3). This productive age indicates that opportunities to develop seaweed farming businesses are still wide open. In addition, this productive age group usually has high energy and adaptability to changes and innovations in cultivation techniques. Thus, they are more likely to implement new practices that can improve the yield and quality of seaweed production. Most farmers in the productive age range indicate the potential for sustainability and regeneration of seaweed farming in the area since they still have a long time to contribute to the sector.

The education level indicates the ability to acquire knowledge and adopt technological innovations in seaweed farming. Seaweed farmers in Bone Regency generally have primary and secondary education (Fig. 3). Low education indicates weak management skills and mastery of new technologies. Low levels of education make it difficult for farmers to switch professions **(Wijayanto *et al*., 2022)**. Limited knowledge and skills due to low education can hinder the adoption of more modern and efficient cultivation techniques **(Kosichek *et al*., 2024)**. In addition, low education also reduces farmers' ability to understand and utilize market information, which is essential for optimizing profits.

Meanwhile, farming experience determines the success of business management. Research data show that the average seaweed farmer has 5-10 years of experience (Fig. 3). This experience is vital in supporting seaweed cultivation in Bone District. Sufficient experience allows farmers to overcome problems in business management. Over the years, farmers have developed in-depth knowledge of the cultivation cycle, optimal environmental conditions, and disease and pest management techniques **(Campbell *et al*., 2022)**. Farmers with less experience tend to be more challenged to improve their seaweed farming to improve their livelihoods. This is because their expertise is limited to seaweed cultivation, thus even if they experience severe crop failure, their routine in seaweed cultivation continues.

The majority of seaweed farmers have three dependents, representing the highest number among them. This shows that family members have enough labor to help manage the business. The presence of family members as laborers provides flexibility and cost efficiency. With the help of family members, farmers can focus more on strategic aspects of seaweed farming, such as planning, resource management, and marketing. It also improves the skills and knowledge of family members in aquaculture, thereby increasing the productivity and welfare of farming families.

Social conditions of seaweed farmers

Land ownership of seaweed cultivation is one of the important aspects that influences the success and sustainability of seaweed cultivation businesses in various regions, including Bone Regency. The study's data showed that, on average, farmers own two plots of land for seaweed cultivation. Adequate land ownership allows farmers to maximize production and manage resources more efficiently (Fig. 4).

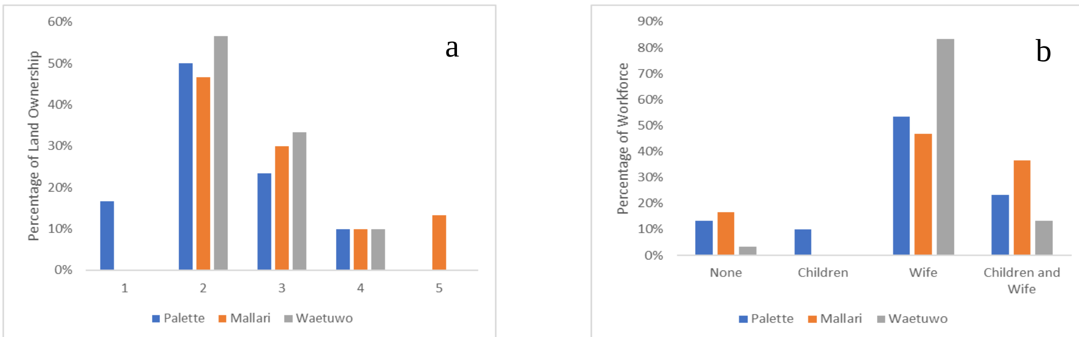

Fig. 4. Social conditions of seaweed farmers. a Total land ownership, b. Labor force

Farmers usually involve family members in seaweed farming as labor fields **(Rimmer *et al*., 2021)**. This reflects the challenge of increasing productivity and efficiency in seaweed farming in Bone District. Limited skills and technical knowledge among family members often hinder the adoption of new technologies and more efficient farming practices. While involving family members can reduce labor costs, productivity remains stagnant without improved capabilities. Additionally, there is a need for more government support, including technical and financial assistance, as well as better infrastructure such as processing and marketing facilities.

Seaweed farmers in Bone Regency predominantly use the long line method for cultivation (Fig. 5). This method is preferred due to its cost-effectiveness and simplicity compared to other methods, such as floating rafts **(Garcia Poza *et al.*, 2020)**. Seedlings are sourced from the farmers' own cultivation, with planting depths ranging from 1 to 20 meters. Cultivation sites are located between 5 and 1,500 meters from the shoreline. The primary type of seaweed cultivated is *Kappaphycus alvarezii*. The ropes used are 25 to 35 meters long, with seedlings spaced 10 to 15cm apart and ropes spaced 0.5 meters apart. The seaweed harvest cycle is approximately 45 days, making it a viable source of monthly income for the community.

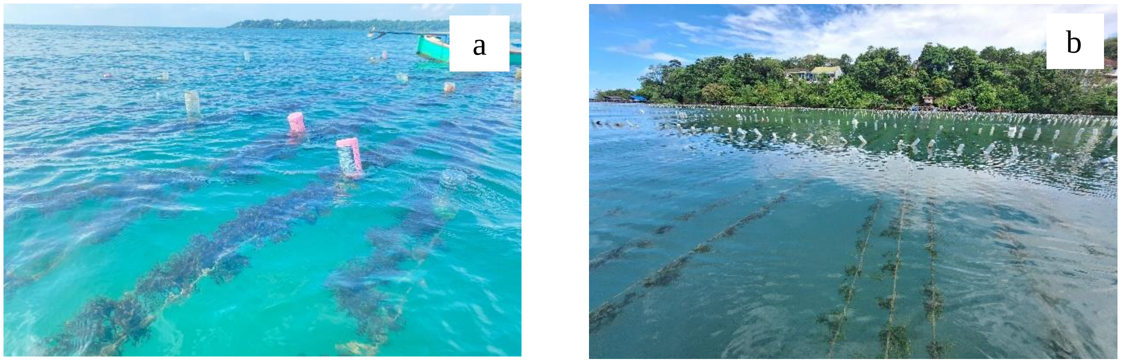

Fig. 5. Long line seaweed cultivation method. **a.** Cultivation locations far from the coastline, **b.** Cultivation location close to the coastline

Economic conditions of seaweed farmers

Several aspects, such as the amount of production, the factual price of dried seaweed, and the marketing of seaweed, explain the economic condition of seaweed farmers in Bone Regency.

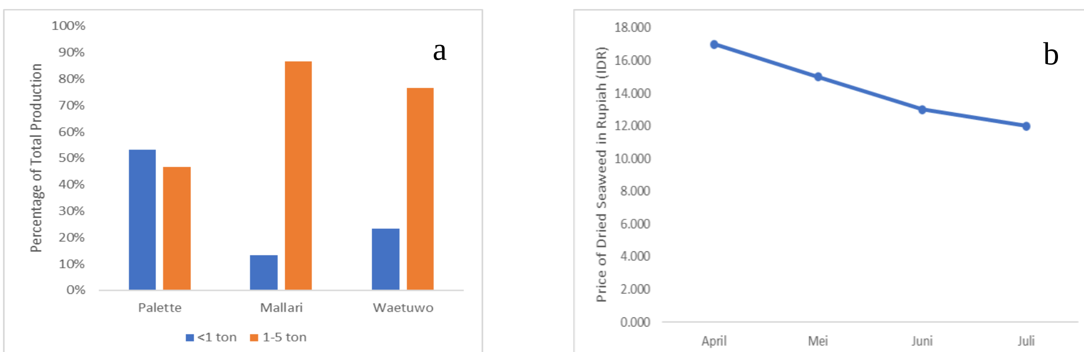

Fig. 6. Economic conditions of farmers. **a.** Total production and **b.** Price of dried seaweed

Based on the interviews, dry seaweed production in Bone District varies from less than one ton to five tons per year. The cultivated land area causes this variation, the cultivation methods used, and environmental and weather conditions. Farmers with larger plots of land tend to produce more. Technical support and training also play an essential role in increasing production **(Snethlage *et al*., 2023)**.

Fluctuating seaweed selling prices are one of the main challenges for farmers in Bone Regency. These price fluctuations directly impact farmers' income and the stability of the local economy. Factors influencing price fluctuations include global market conditions, product quality, and weather changes. Dried seaweed prices fell from IDR 17,000/kg to IDR 12,000/kg between April and July 2024. This price decline caused many farmers to suffer losses and have difficulty meeting their daily needs. Price uncertainty makes it difficult for farmers to plan and develop their businesses. Low prices at the farm level seriously hamper the potential for income generation **(Mantri *et al*., 2022)**. With uncertain incomes, farmers need help accessing capital for investments in technology or better infrastructure, which would otherwise increase productivity and crop quality.

The availability of seaweed stocks also contributes to price fluctuations and quality declines, as many traders compete to secure seaweed supplies to store in their warehouses. As a result, these traders purchase seaweed regardless of price and quality to reduce potential shortages; if the quality is low, the price offered is also low, so fishers lose bargaining power **(Sarmin *et al*., 2021; Muflikh *et al*., 2024)**. Traders play an essential role in increasing the value of seaweed products through various activities such as drying, sorting, and storage **(Muflikh *et al*., 2024)**. In Bone District, seaweed farmers depend on traders to sell their harvest to them for immediate cash. Each trader has a regular seller and offers different prices. However, farmers rarely cut ties with buyers out of fear. This condition hinders the development of seaweed farming because farmers only receive information from one party. For farmers, the relationship is profitable and provides a sense of security.

Seaweed farming management strategy

Seaweed aquaculture management strategies in Bone Regency are based on analyzing internal and external factors using the IFE (Internal Factors Evaluation) and EFE (External Factors Evaluation) matrices. This analysis aims to assess the strategic factors that influence the success of the recommended strategy. Internal factors are evaluated based on strengths and weaknesses, while external factors are evaluated based on opportunities and threats. Weighting and ranking of each factor is done to determine its score based on the data obtained. This analysis provides a comprehensive picture of the strategic position of seaweed farming. The analysis results of internal and external strategic factors can be seen in Tables (1, 2).

Table 1. Internal strategy factors

Internal strategy factors	**Weight**	**Rating**	**Score**
Strength			
Strong community character as cultivators (S1)	0.11	4	0.43
Seaweed cultivation labor from family members and surrounding communities (S2)	0.11	4	0.43
Marketing of cultivation products is quite easy to sell (S3)	0.10	3	0.31
Cultivators are of productive age (S4)	0.11	4	0.43
Cultivator experience (S5)	0.11	4	0.43
Total			**2.03**
Weakness			
Traditional cultivation techniques (W1)	0.11	3	0.32
Lack of role of extension workers in cultivation assistance (W2)	0.07	1	0.07
Sales system is still tied (W3)	0.07	2	0.14
There is no specialized seaweed cultivation group (W4)	0.11	1	0.11
Education level is still weak (W5)	0.11	1	0.11
Total			0.75
Strengths - Weaknesses			**1.28**

Table 2. External strategy factors

External strategy factors	**Weight**	**Rating**	**Score**
Opportunity			
Seaweed is a national superior commodity (O1)	0.12	4	0.46
Growing demand (O2)	0.12	4	0.46
Offshore waters that can be optimally utilized (Q3)	0.12	3	0.35
for seaweed cultivation according to the RZWP3K (O4)	0.10	3	0.29
Technology development (O5)	0.10	2	0.19
Total	0.54		**1.75**
Threat			
Climate change (T1)	0.08	2	0.15
Pest and disease attacks (T2)	0.12	3	0.35
Fluctuations in seaweed prices (T3)	0.12	1	0.12
No permanent partners (T4)	0.12	2	0.23
The community lacks knowledge of zoning or spatial planning for cultivation and other activities (T5)	0.04	1	0.04
Total			0.88
Opportunities - Threats			**0.87**

The results of the IFE analysis show that the strength factor has a value of 2.03, while the weakness has a value of 0.75. This indicates that existing strengths can be used to minimize weaknesses. Meanwhile, the EFE analysis shows that the opportunity factor has a value of 1.75, while the threat factor has a value of 0.88. This indicates that existing opportunities can be utilized to overcome threats.

Based on the calculation of the total IFE and EFE scores, the IFE value is 1.28, and the EFE value is 0.87. These values are plotted on the SWOT diagram, resulting in a point in quadrant 1 supporting an aggressive strategy. This situation is favorable for determining strategies for managing seaweed aquaculture in Bone Regency. The strategy matrix can be seen in Fig. (7)

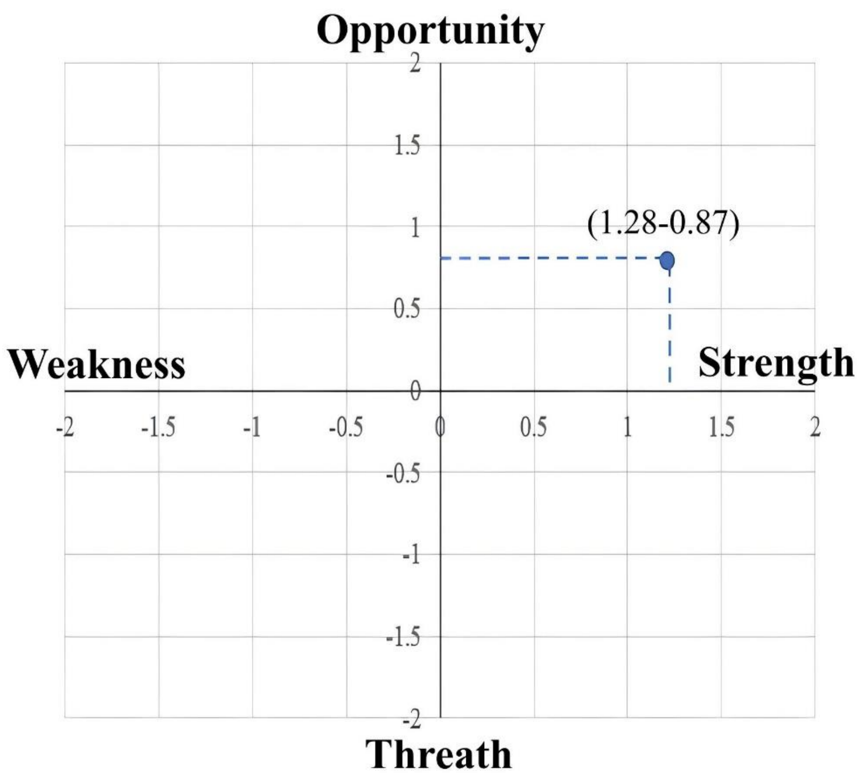

Fig. 7. SWOT strategy matrix

Spatial recommendations for seaweed cultivation management strategies

Appropriate zoning for cultivation areas must consider the environment's carrying capacity and the protection of coastal and marine ecosystems to prevent degradation. Zoning rules based on the coastal zone and small islands zoning plan (RZWP3K) must comply with the provincial spatial plan **(Muflikh *et al*., 2024)**. Based on the research results, some cultivation locations are outside the cultivation zone of the RZWP3K of South Sulawesi Province, namely in the conservation zone and tourism zone.

This indicates a mismatch between the community's cultivation practices and the established spatial plan. This mismatch can result in various negative impacts, including damage to the coastal and aquatic environment and potential land use conflicts between interested parties. Therefore, evaluating and adjusting existing cultivation practices to align with established spatial plans is essential. In addition, there is a need for an increased coordination between local governments, communities, and other stakeholders to ensure that seaweed farming activities are sustainable and not detrimental to the environment.

Monitoring and enforcing zoning violations is essential to ensure compliance with the South Sulawesi Province Coastal Zone and Small Islands Zoning Plan (RZWP3K), designated as a mariculture development **(Sutaman *et al*., 2023)**. In addition, education and training for the community on sustainable aquaculture techniques and the importance of preserving the environment must be improved. This strategy is expected to support the effect of sustainable management of marine space utilization by seaweed farmers; anticipated aquaculture management can run more optimally and provide benefits to the environment and local economy; recommendations for marine space utilization according to its utilization zone based on data from the Coastal Zone and Small Island Zoning Plan (RZWP3K) 2019-2039 presented in Fig. (8).

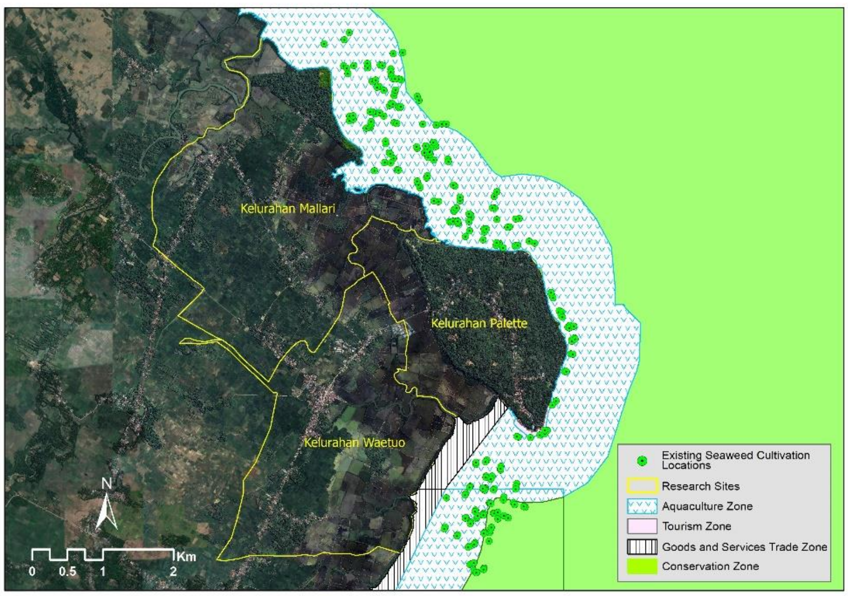

Fig. 8. Spatial recommendations for seaweed aquaculture management based on South Sulawesi Province RZWP3K 2019-2039

The zoning plan along the coastal area of the study location depicted in Fig. (8) indicated by the green buffer, represents the region where the government permits aquaculture activities. The mapping of existing seaweed cultivation sites (green points) within the study area shows that the actual seaweed farming locations are consistently within the government-regulated boundaries. However, in some places, the cultivation areas have reached the margin/boundary and, in a few cases, even slightly exceeded the boundary line. This situation requires special attention from the government to address and provide solutions to the seaweed farmers.

CONCLUSION

Based on the research results, it can be concluded that the seaweed aquaculture management strategy is an SO strategy with the following results: 1) Increase community involvement in government programs that support the development of seaweed cultivation as a superior commodity by utilizing local wisdom and community experience; 2) Develop training and education for the community to improve seaweed cultivation skills to increase the productivity and quality of cultivation products to meet the increasing demand; 3) Optimizing local and national marketing networks, using digital marketing strategies, and expanding access to international markets; and 4) Encourage productive-age farmers to utilize optimal land by the RZWP3K to increase the area of cultivation sites.

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