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# Sustainability Analysis of Seaweed Cultivation as Regional Economic Resource in Raijua District

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**Abstract**

This study investigates the sustainability of seaweed cultivation as a strategic economic resource and its implications for community welfare in Raijua District, Sabu Raijua Regency, Indonesia. Employing a qualitative case study approach, data were collected through interviews, observations, and documentation involving key stakeholders, including seaweed farmers, local authorities, and marine experts. The research aims to explore the socio-economic, environmental, and institutional factors influencing the sustainability of seaweed farming, and to assess its potential in supporting regional economic development. Findings reveal that the sustainability of seaweed cultivation is shaped by multiple interrelated factors such as environmental conditions, site selection, cultivation technology, farmer management skills, market access, infrastructure, government policy, education, and institutional collaboration. These factors directly affect productivity, resilience, and the long-term viability of seaweed farming. The study also highlights the positive impacts of seaweed cultivation on community welfare through income generation, reduced urban migration, empowerment of marginalized groups, economic diversification, and the growth of micro and small enterprises. Furthermore, environmentally friendly cultivation practices contribute to marine ecosystem conservation, carbon sequestration, and sustainable resource management. The study concludes that seaweed cultivation, when supported by integrated policy frameworks and stakeholder cooperation, can serve as a sustainable livelihood strategy and an engine for regional economic growth. These insights are valuable for policymakers, development practitioners, and researchers focusing on sustainable aquaculture and coastal economic resilience in developing regions.

## 1. Introduction

Seaweed has long been recognized as a valuable marine resource with diverse applications across multiple sectors. Globally, seaweed is widely utilized in the food industry, pharmaceuticals, cosmetics, animal feed, fertilizers, paper production, and bioenergy, primarily due to its rich nutritional profile and bioactive compounds (Khan et al., 2018). Among the most commercially important species is *Eucheuma cottonii*, a red algae known for its carrageenan content, which plays a significant role in food processing and various industrial applications. Historical records indicate that seaweed has been part of human life since 2,700 BC, emphasizing its longstanding socio-economic relevance.

Indonesia, as a maritime nation with abundant coastal ecosystems, holds considerable potential in seaweed aquaculture. One of the emerging areas with promising cultivation conditions is Raijua Sub-district in Sabu Raijua Regency, East Nusa Tenggara. Surrounded by unpolluted open seas and supported by natural ecological advantages, Raijua is particularly suitable for the cultivation of *Eucheuma cottonii*. However, despite its environmental potential, the region has not fully realized the benefits of marine aquaculture. Seaweed farming remains underdeveloped, with production volumes and community income levels far below national averages.

Empirical studies (e.g., Fitriana et al., 2020; Nurhayati & Sulaeman, 2021) have identified similar constraints in other coastal regions of Indonesia, such as limited access to markets, inadequate infrastructure, poor cultivation techniques, and institutional fragmentation. Yet, research specifically focused on the sustainability of seaweed farming in the socio-ecological context of Raijua

remains scarce. Existing literature often generalizes findings across larger provinces without considering the unique biophysical, economic, and cultural characteristics of remote island communities like Raijua.

This study aims to fill that gap by evaluating the sustainability of seaweed farming in Raijua through a comprehensive analysis of its environmental, economic, and social dimensions. The core objective is to determine whether seaweed cultivation can serve as a sustainable livelihood strategy for improving local welfare. In doing so, the study will also identify enabling and constraining factors that influence seaweed-based economic development in coastal areas.

The academic contribution of this research lies in providing a context-specific understanding of sustainable aquaculture in a marginalized and understudied region. It also adds to the broader discourse on the blue economy by offering policy-relevant insights into how local marine resources can be harnessed responsibly. Given the global momentum toward sustainable coastal livelihoods and marine-based economic resilience, this study is both timely and essential for informing development strategies in archipelagic regions like Sabu Raijua.

## 2. Literature Review

### 2.1 Definition and Types of Seaweed

Seaweed is a type of benthic macroalgae that typically grows attached to substrates in coastal and intertidal zones. Classified within the Thallophyta division, seaweed lacks true roots, stems, and leaves; instead, it consists of a thallus that performs all essential physiological functions. The thallus may take various forms cylindrical, flattened, or irregular depending on the species and environmental conditions (Gumilar, 2021).

Seaweed absorbs nutrients directly from the surrounding water through diffusion across its thallus surface. Sunlight, water temperature, salinity, and nutrient availability are critical to its growth and reproduction. Seaweed plays an essential ecological role in coastal ecosystems and serves as a significant raw material in the global market.

Various economically valuable species of seaweed include:

- *Gelidium sp.*
- *Gracilaria verucossa*
- *Eucheuma spinosum*
- *Eucheuma cottonii*
- *Acantophora spicifera*
- *Chondrococcus hornemannii*
- *Hypnea sp.*
- *Ulva lactuca*

### *2.2 Seaweed Cultivation*

Seaweed cultivation has emerged as a viable aquaculture practice, contributing to national food security, employment generation, and export earnings. The process involves selecting appropriate locations and applying suitable cultivation techniques to ensure sustainable yield (Ramadhan, 2019).

Key stages in cultivation include:

1. **Site Selection**: Ideal locations have calm waters, moderate salinity, depths of 70–200 cm depending on tides, and low pollution levels. Slightly sandy or muddy substrates and well-functioning water channels are also required.
2. **Cultivation Methods**:
   - **Bottom Method**: Seaweed is tied and anchored to the seabed or coral structures.
   - **Floating Method**: Utilizes buoys on the sea surface; includes floating net and floating rope systems.
   - **Off-Bottom Method**: Involves suspending seaweed from horizontal nylon lines; subtypes include single-line, net, and tubular designs.

### *2.3 Sustainability of Seaweed Cultivation*

Sustainability is defined as the balanced utilization of resources to meet present needs without compromising the ability of future generations to meet theirs. In the context of seaweed cultivation, sustainability requires careful attention to environmental impact, economic viability, and social equity.

Sustainable cultivation practices aim to:

- Preserve marine biodiversity
- Prevent coastal degradation
- Promote long-term community welfare These goals align with the broader objectives of sustainable development, which are increasingly important in global and national aquaculture policies.

### *2.4 Regional Economy*

Regional economics explores the interactions between economic activities and geographic locations, focusing on how regions grow and manage resources. According to Sjafrizal (2012), this field examines policy interventions to stimulate economic growth, reduce inequality, and improve living standards at the local level.

In coastal regions like Raijua, marine resources such as seaweed represent vital economic drivers. Seaweed cultivation, when effectively managed, can create employment, stimulate local businesses, and reduce dependency on external economic inputs.

### *2.5 Theoretical Framework*

1. **Economic Development Theory** Suparmoko (2007) and Sukirno argue that economic development is a long-term process aimed at improving per capita income and overall productivity. Seaweed cultivation fits this model as it contributes to income growth and economic diversification in coastal communities.
2. **Environmental Economics Theory** According to Murni (2016), environmental economics studies how economic activities impact ecological systems. This theory supports analysis of how seaweed farming affects marine ecosystems, emphasizing the need for environmentally conscious practices.
3. **Sustainability Theory (SDGs)** Sustainable development encompasses economic, social, and environmental goals. Ciptadi (2023) highlights the importance of balancing these dimensions in marine-based economies to ensure intergenerational equity and resilience.
4. **Social Capital Theory** Baker and Schiff suggest that networks, trust, and norms enable collective action. In seaweed farming communities, strong social capital can facilitate cooperation, knowledge sharing, and conflict resolution.
5. **Institutional Theory** Vipriyanti (2018) explains that formal and informal institutions shape individual and organizational behavior. Understanding local governance, traditions, and community structures is critical to implementing sustainable seaweed farming models.

## 3. Research Methods

### *3.1 Type of Research*

This study uses a **qualitative research design** with a **case study approach**. The case study method is ideal for exploring complex social phenomena within their real-life context (Yin, 2018). The research aims to gather in-depth information from multiple stakeholders—such as seaweed farmers, local officials, entrepreneurs, and environmental experts—to understand the contribution of seaweed cultivation to sustainable regional economic development in Raijua District.

### *3.2 Research Approach*

A **qualitative approach** was chosen to obtain a deep and holistic understanding of the social and environmental dynamics surrounding seaweed cultivation. According to Creswell (2014), this approach enables the researcher to interpret meaning derived from social experiences, behaviors, and interactions. It involves close engagement with participants, allowing for narrative-rich and context-sensitive insights into their lived realities.

### *3.3 Research Focus*

This study focuses on examining how sustainable seaweed cultivation affects the economic welfare of communities in Raijua District. The research evaluates sustainability from three key dimensions: **environmental,**

**economic, and social**, in line with the **Triple Bottom Line** framework (Elkington, 1997).

### *3.4 Types and Sources of Data*

#### 3.4.1 Types of Data

- **Qualitative Data:** Information related to policies, perceptions, and local practices concerning seaweed sustainability, collected through interviews and field observations.
- **Quantitative Data:** Seaweed production statistics from 2018–2022 obtained from the Sabu Raijua District's Fisheries and Marine Affairs Office and the Central Bureau of Statistics (BPS).

#### 3.4.2 Sources of Data

- **Primary Data:** Sourced directly from key informants including the sub-district head, village leaders, seaweed farmers, and daily laborers. Data were obtained through interviews and observations (Sumaryadi, 2020).
- **Secondary Data:** Derived from existing documentation, policy reports, publications, and previous research related to seaweed farming and regional development.

### *3.5 Data Collection Techniques*

#### 3.5.1 Observation

Direct observation was conducted to understand cultivation practices and the work environment of seaweed farmers in Raijua. The researcher recorded field notes and visual documentation to capture farming techniques and community participation.

#### 3.5.2 Interview

Semi-structured interviews were used to collect rich, flexible data. Questions were guided by the study objectives but adapted during the conversation to explore deeper issues. Informants included farmers, business owners, and government officials.

#### 3.5.3 Documentation

Documents such as government reports, community development plans, photographs, and visual media were analyzed to support and validate field findings (Bungin, 2008).

### *3.6 Data Analysis Techniques*

#### 3.6.1 Data Analysis Stages

Data were analyzed following Creswell's (2014) six-step qualitative analysis procedure:

1. Organizing and preparing the data.
2. Reading the entire dataset.
3. Coding the data.
4. Generating themes from codes.
5. Presenting findings narratively.
6. Interpreting data in light of relevant theories.

#### 3.6.2 Data Validity

To ensure data credibility, **triangulation** techniques were applied (Patton, 2002):

- **Source Triangulation:** Comparing data from interviews, observations, and documentation.
- **Method Triangulation:** Using multiple methods to confirm consistency.
- **Theoretical Triangulation:** Analyzing findings through multiple theoretical lenses, including:
  - **Sustainable Livelihoods Framework** (Chambers & Conway, 1992)
  - **Blue Economy Theory** (Pauli, 2010)
  - **Social Capital Theory** (Putnam, 2000)
  - **Regional Development Theory** (Todaro & Smith, 2015)
  - **Environmental Economics** (Tietenberg & Lewis, 2018)
  - **Institutional Theory** (North, 1990)

These theories serve as the conceptual foundation to understand how social, economic, and institutional dynamics shape sustainable aquaculture in remote island contexts.

## 4. Results and Discussion

### 4.1 Research Results

#### 4.1.1 Factors Affecting the Sustainability of Seaweed Cultivation Business in Raijua District

1. **Environmental Conditions**

   The sustainability of seaweed cultivation in Raijua District is significantly influenced by environmental factors such as water salinity, temperature, clarity, and ocean currents. Optimal conditions—high salinity, stable

temperatures, and suitable depths—support healthy growth and high-quality harvests. Conversely, pollution and extreme environmental changes, such as those triggered by climate change or unsustainable human activities, can disrupt marine ecosystems and negatively affect production.

2. **Location Selection**
   Strategic selection of cultivation areas plays a crucial role in ensuring optimal harvest outcomes. Locations shielded from strong currents, storms, and pollution are more likely to maintain stable production. Additionally, proximity to transportation infrastructure facilitates efficient product distribution. The study indicates that farmers who select cultivation sites based on these considerations tend to experience higher success and long-term business continuity.

3. **Cultivation Technology and Methods**
   The use of advanced technologies and adaptive cultivation methods, such as high-quality seeds and locally appropriate planting techniques, has demonstrably improved productivity in Raijua District. Innovations like water quality monitoring sensors and floating systems contribute to increased production efficiency. Continuous improvement and farmer adoption of such technologies are essential to enhance the competitiveness and sustainability of the sector.

4. **Management and Skills**
   Farmer competencies in both technical and managerial aspects—ranging from planting techniques to financial and marketing management—significantly affect business sustainability. Farmers with better planning, record-keeping, and strategic decision-making capabilities are more resilient to challenges such as price volatility and environmental changes. Sound management also enables better risk mitigation.

5. **Market and Price Stability**
   A stable and accessible market is essential for business viability. The study finds that price volatility and limited access to broader markets remain persistent challenges for farmers. Sudden price drops can reduce profit margins, while market isolation hampers expansion. Strengthening market linkages and ensuring price support mechanisms are critical for sustainability.

6. **Government Policy**
   Government support in the form of subsidies, training programs, infrastructure development, and regulatory frameworks plays a key role in advancing the seaweed industry. Informants emphasized the need for more consistent and targeted policy interventions to empower local farmers and sustain the growth of the industry in Raijua.

7. **Infrastructure Support**
   Adequate infrastructure including roads, ports, electricity, and clean water directly affects production capacity, product quality, and logistics efficiency. Improved infrastructure reduces operational costs and enhances the profitability of seaweed farming businesses.

8. **Environmental Sustainability**
   The health of the marine ecosystem is foundational to the continuity of seaweed cultivation. Water pollution, coral reef degradation, and unregulated activities threaten ecosystem balance. Integrating environmental safeguards into cultivation practices is essential to maintain biodiversity and long-term productivity.

9. **Education and Training**
   Capacity building through training and education is vital for equipping farmers with the knowledge and skills to improve productivity and adapt to dynamic environmental and market conditions. The study shows that trained farmers are more innovative and better able to manage risks.

10. **Collaboration and Networking**

The sustainability of seaweed farming is also influenced by collaboration among stakeholders—farmers, private sector actors, government agencies, and NGOs. Networking facilitates knowledge exchange, collective problem-solving, and broader market access, which in turn fosters resilience and industry development.

### 4.1.2 Sustainability of Seaweed Cultivation Business Can Drive Economic Growth in Terms of Social, Economic and Environmental Aspects, in Improving Community Welfare in Raijua District

**1. Social Aspects**

**a) Increased Income and Welfare**

Seaweed cultivation has significantly contributed to raising household income in coastal communities of Raijua. Many families who previously lived in economic hardship now benefit from a more stable income, allowing better access to education, healthcare, and housing. This translates into an improved standard of living and enhanced community welfare.

**b) Reduction of Urbanization**

The availability of jobs in seaweed farming has helped mitigate rural-urban migration. The sector provides viable employment opportunities within the village, reducing the need for residents to seek work in urban areas. This helps preserve local culture and strengthens community cohesion.

**c) Empowerment of Vulnerable Groups**

Seaweed farming creates inclusive opportunities, particularly for women and marginalized groups. Their involvement not only contributes to household income but also enhances their social standing. This empowerment promotes gender equity and greater participation in community development.

**2. Economic Aspects**

**a) Diversification of the Local Economy**

Seaweed farming has diversified income sources beyond traditional agriculture and fishing. This diversification reduces vulnerability to seasonal and market fluctuations, promoting a more resilient local economy.

**b) Increasing Added Value**

The economic potential of seaweed can be enhanced through value-added processing. However, limited access to modern processing technology remains a constraint. Investment in equipment and training can boost efficiency, improve product quality, and increase overall income.

**c) Growth of Micro and Small Enterprises**

The seaweed industry has stimulated the emergence of micro and small enterprises, particularly in processing, logistics, and marketing. These businesses generate new employment opportunities and contribute to local economic dynamism.

**3. Environmental Aspects**

**a) Conservation of Marine Ecosystems**

Environmentally friendly cultivation practices help conserve marine ecosystems. Seaweed reduces coastal erosion, improves water quality, and provides habitats for marine species. These ecological benefits are essential for long-term marine resource sustainability.

**b) Carbon Emission Reduction**

Seaweed absorbs carbon dioxide during photosynthesis, contributing to carbon sequestration. This function supports global efforts to mitigate climate change and positions seaweed cultivation as a climate-smart practice.

**c) Sustainable Resource Management**

The adoption of sustainable practices—such as avoiding overharvesting, rotating cultivation areas, and maintaining ecosystem balance—ensures long-term resource availability. This study shows that resource management practices in Raijua are progressing toward ecological sustainability.

## 4.2 Research Discussion

### 4.2.1 Factors Affecting the Sustainability of Seaweed Cultivation Business in Raijua District

#### 1. Environmental Conditions

Based on research conducted in Raijua District, it was found that water quality and sea conditions play a vital role in the success of seaweed cultivation. This is in line with several previous studies that emphasize the importance of the environment in maintaining the sustainability of cultivation efforts. According to research by Lobban and Harrison (1994), factors such as water temperature, salinity, and water clarity affect the photosynthesis process and seaweed growth. High optimal salinity helps maintain osmotic pressure in seaweed tissue, thus supporting better growth. This study also revealed that water temperatures ranging from 28°C to 30°C are ideal conditions for seaweed, as conveyed by informant Mr. Anton Kudji S.Pi. Another study by McHugh (2003) confirmed that changes in water temperature due to climate change, especially rising temperatures, can slow the growth rate of seaweed and increase the risk of disease.

Water clarity is also an important factor that needs to be considered. As expressed by Anton Kudji, sedimentation due to human activities and climate change can reduce water clarity, which in turn reduces the intensity of light received by seaweed for photosynthesis. This is reinforced by research by Zemke-White and Ohno (1999) which states that optimal water clarity is very important for light penetration required for photosynthesis, especially in cultivation areas with calm water currents.

#### 2. Location Selection

The selection of a cultivation location is a fundamental factor that greatly influences the sustainability of seaweed cultivation efforts. In a study conducted in Raijua District, it was identified that the location chosen by considering the right environmental factors greatly influences the success of cultivation. This is supported by many studies that show the importance of selecting a strategic location in supporting the productivity and quality of seaweed products. According to research by Mumford and Miura (1988), locations with clear water and the right depth provide enough sunlight to support seaweed photosynthesis, which is an important factor in growth and production. Water clarity helps the penetration of sunlight needed by seaweed, so that the photosynthesis process can take place optimally. The study also emphasized that small waves and moderate ocean currents can avoid physical damage to plants, especially to cultivation structures such as moorings and anchors.

An interview with Mrs. Anita Migo Daga, a seaweed farmer in Raijua, emphasized the importance of considering several aspects in selecting a location, as also mentioned in the literature. For example, Trono (1999) stated that waves that are too strong can damage the physical condition of seaweed, especially in the early stages of growth. Therefore, a location protected from large waves is highly recommended to maintain the integrity of the plants.

#### 3. Cultivation Technology and Methods

Technology and cultivation methods in seaweed farming businesses show that the use of appropriate technology and efficient cultivation methods can increase productivity and the quality of the harvest. In the context of seaweed farming in Raijua District, research shows that although many farmers still use traditional methods, there is great potential in adopting modern technology to support the sustainability and competitiveness of their businesses.

According to Trono (1999), traditional methods such as the use of mooring ropes and nets are still widely used in various regions of Southeast Asia. Although this method has proven to be quite effective and easy to apply, this technique has limitations in terms of labor efficiency and harvest quality. The use of manual tools often slows down the planting and

harvesting process, and has the potential to increase crop damage during bad weather.

**4. Management and Skills**

Farmers who are able to practice good financial management tend to be better prepared to face fluctuations in seaweed prices in the global market, as is often the case with this commodity. Proper management also allows farmers to make strategic decisions, such as when to plant, harvest, or sell their produce to maximize income.

Based on an interview with Mr. Yulius Kudji, management skills among seaweed farmers in Raijua District are still relatively low, especially in terms of managing income and implementing efficient cultivation techniques. This indicates limited access to information and training needed to improve farmers' skills. Neish (2008) also emphasized that low management skills are often exacerbated by a lack of access to training and information, especially in remote areas such as Raijua.

**5. Market and Price**

Markets and prices are key elements in determining the sustainability of seaweed farming, especially for farmers in remote areas such as Raijua District. Research shows that significant price fluctuations, high transportation costs, and limited access to wider markets are the main challenges for seaweed farmers in this area. Uncertainty regarding prices and markets affects farmers' income, potentially threatening the sustainability of their businesses.

According to Valderrama et al. (2015), the international market plays an important role in determining seaweed prices, especially for major producing countries. Seaweed prices are often determined by global demand for seaweed derivative products such as carrageenan, agar, and alginate. This study also emphasizes that the seaweed market is very sensitive to changes in the global economy, consumer demand, and international trade regulations. This is relevant to the situation in Raijua District, where seaweed prices are greatly influenced by international market conditions, as explained by informant Mr. Lukas Kaka Balo.

**6. Government policy**

Government policies play a significant role in supporting the sustainability of seaweed farming, especially in areas such as Raijua District. Research shows that government interventions, such as technical assistance, subsidies, and environmentally friendly regulations, can help farmers overcome the various challenges they face, including access to technology, markets, and financial support. According to Graham et al. (2014), government policies that support farmers through subsidy and training programs are very important to increase the productivity and efficiency of farming businesses.

In the context of Raijua District, information from Mr. Leo Huru shows that assistance in the form of seeds, fertilizers, and farming equipment, such as ropes and wooden shells, has had a positive impact on farmers' ability to reduce production costs. This is in line with the findings of Cohen et al. (2016) who stated that direct subsidies for agricultural inputs can increase farmers' production capacity and income, as well as reduce their dependence on expensive resources. Training provided by the government and related agencies also plays an important role in improving farmers' skills. Boko et al. (2020) emphasized that proper training on efficient farming techniques can help farmers adopt better and more sustainable practices. This has the potential to increase crop yields and product quality, which is critical in enhancing competitiveness in the market.

**7. Infrastructure Support**

Adequate infrastructure support is one of the key factors in supporting the sustainability of seaweed farming businesses in Raijua District. Research shows that areas with good infrastructure are able to overcome logistical challenges and minimize post-harvest losses, which have a positive impact on business

efficiency and profitability. According to Bakker et al. (2016), good infrastructure, including road access and transportation facilities, greatly influences farmers' ability to distribute their products. Information from Mr. Yos Nadjo underlines the importance of good road access to facilitate transportation of harvested crops to collectors or ports. Poor road conditions, especially during the rainy season, as expressed by informants, can result in high transportation costs and delays in product delivery, which in turn affect the quality and selling price of seaweed. This is in line with research by Smith et al. (2018) which states that poor transportation infrastructure can lead to significant increases in post-harvest costs and losses.

**8. Environmental Sustainability**

Environmental sustainability is a crucial factor in ensuring the success and sustainability of seaweed farming in Raijua District. Research shows that environmentally friendly and sustainable farming practices can maintain marine ecosystems, increase productivity, and minimize negative impacts on the environment. According to Barbier et al. (2011), sustainable farming practices are important to protect marine ecosystems from negative impacts such as pollution and over-exploitation. Information from Mr. Anton Kudji S.Pi, who stated that public awareness in Raijua in maintaining the marine environment has increased, shows that collaborative efforts between the government and local communities can produce positive results. Pollution control, as stated, is an important step to maintain water quality and ecosystem health.

**9. Education And Training**

Proper education and training are key components in improving the efficiency and sustainability of seaweed farming. Research shows that farmers in Raijua District who receive training tend to be better able to face challenges, increase productivity, and manage their businesses better. According to Kumar and Singh (2013), education and training that focuses on cultivation techniques and business management have a significant impact on agricultural output, including seaweed farming. Information from Mr. Djibrael Radja Kudji S.Pd confirmed that the government has implemented training programs on cultivation techniques and post-harvest management. This is in line with findings that show that adequate training helps farmers to adopt more efficient and adaptive practices to environmental changes, as stated by Kassam et al. (2012).

**10. Cooperation and Networking**

Good cooperation and networking between farmers, entrepreneurs, and research institutions are essential in improving the sustainability of seaweed farming in Raijua District. This study shows that effective collaboration can improve productivity, innovation, and access to markets, all of which contribute to business success. According to Dyer and Singh (1998), cooperation between actors in the value chain can create competitive advantages and improve operational efficiency. Information from Mr. Lukas Kaka Balo confirms that cooperation between farmers and entrepreneurs ensures a stable and quality supply of seaweed. This is in line with the findings of Mason and Leek (2008), which show that good relationships between farmers and collectors improve access to market and price information needed for better decision making.

**4.2.2 Sustainability of Seaweed Cultivation Business Can Drive Economic Growth in Terms of Social, Economic and Environmental Aspects, in Improving Community Welfare in Raijua District**

**1. Social Aspects**

**a) Increased Income and Welfare**

Seaweed cultivation in Raijua District has significantly increased the income of local communities, especially in coastal areas. This is in accordance with the findings of Hassan et al. (2018) which show that the fisheries and aquaculture sectors can contribute to increasing the income and welfare of coastal communities. The informant, Mr. Degi Kaka

Balo, revealed that many families are now able to meet basic needs such as education and health thanks to the additional income from seaweed cultivation. Mrs. Marce Adju's statement also emphasized that the visible economic growth provides better access to health and education services. Overall, the additional income from seaweed cultivation allows families to be more financially independent, improve their quality of life, and increase access to basic services. This shows that seaweed cultivation is not only about the economy, but also a broader social aspect.

**b) Reduction of Urbanization**

The seaweed farming sector also plays a role in reducing urbanization. As expressed by Mr. Ruben Radja Gewi, many families choose to remain in the village because of the available job opportunities. This finding is in line with research by Baker and Kauffman (2009) which states that the presence of local jobs can reduce the urge to migrate to the city. This reduction in urbanization not only maintains the social and cultural structure of the village but also provides economic stability. Ms. Ester Djara added that involvement in seaweed farming makes people feel more confident to live in the village, which in turn strengthens the local community.

**c) Empowerment of Vulnerable Groups**

Seaweed farming also provides empowerment opportunities for vulnerable groups, especially women. Mr. Richard Kore noted that women involved in seaweed farming now have a significant role in production and processing. Research by Kabeer (2015) shows that increasing women's participation in economic activities contributes to gender equality and improved social status. Mr. Lodi Pau added that women not only gain income but also higher self-confidence, which supports solidarity among women. Thus, seaweed farming serves as an empowerment tool that increases inclusivity and equality in society.

**2. Economic Aspects**

**a) Diversification of Local Economy**

Seaweed farming in Raijua District has introduced significant diversification into the local economy, which previously relied heavily on traditional agriculture and fisheries. As stated by Gonzalez et al. (2020), economic diversification can increase community resilience to market fluctuations. Mr. Markus Kudji emphasized that seaweed farming has reduced dependence on a single source of income, providing greater economic stability. This was also supported by Mr. Markus Duke, who emphasized that the additional income from seaweed helped them feel more economically secure, especially when yields from other sectors were inadequate. Overall, this diversification not only strengthens the local economy but also increases community resilience to changes in the market.

**b) Increasing Added Value**

Initiatives to process seaweed into value-added products, such as agar-agar and cosmetics, show great potential in increasing income. However, as stated by Kumar and Sharma (2019), the main challenge in developing this sector is the limitation of technology. Mr. Bastian Talo stated that although the processing potential is very large, currently the existing facilities and technology are still limited. This was also reinforced by Mr. Jefri Haba Rubu who emphasized the need for investment to improve processing technology in order to maximize the potential of seaweed. With the development of the right technology, the potential for increasing income through processed products can be achieved, thus making a significant contribution to local economic growth.

**c) Growth of Micro and Small Businesses**

Seaweed cultivation also encourages the growth of micro and small businesses, especially in distribution and marketing. Research by Verma and Singh (2021) shows that the growth of supporting sectors can increase local economic dynamics. Informant Lukas Kaka Balo stated that with the increase in

seaweed production, many new businesses have emerged to handle distribution and marketing, which not only creates jobs but also expands the market. Mr. Simon Udju's statement emphasized that the growth of these micro and small businesses provides opportunities for family members and other villagers, contributes to improving the welfare of local communities and creates more economic dynamics.

### 3. Environmental Aspects

#### a) Conservation of Marine Ecosystems

Environmentally Environmentally friendly seaweed cultivation practices contribute significantly to the conservation of marine ecosystems in Raijua District. Mr. Anton Kudji S.Pi, as a marine environmental expert, emphasized that seaweed plays a role in reducing coastal erosion and providing habitat for marine species, which supports biodiversity. Research by Barbier et al. (2019) shows that sustainable cultivation practices can maintain the balance of marine ecosystems and water quality. Mr. Leo Huru, a seaweed farmer, emphasized the importance of avoiding hazardous chemicals and maintaining proper planting distances to maintain ecosystem health. By implementing sustainable practices, seaweed cultivation can provide economic benefits while protecting the environment, which is important for future generations.

#### b) Carbon Emission Reduction

Seaweed farming also has the potential to reduce carbon emissions. Mr. Anton Kudji S.Pi explained that during photosynthesis, seaweed absorbs $CO_2$, which contributes to climate change mitigation. According to Mazzola et al. (2021), seaweed's ability to absorb carbon makes it an important tool in global efforts to reduce the carbon footprint. Mr. Markus Duke added that more farmers are aware of the environmental benefits of seaweed farming, which can increase the effectiveness of carbon sequestration. With proper training and education, this practice can be maximized to support global initiatives to address climate change.

#### c) Sustainable Resource Management

Sustainable management of marine resources is key to the sustainability of seaweed farming. Mr. Anton Kudji S.Pi stated that avoiding overexploitation and pollution is an important step to maintain environmental health. Research by Hawkins et al. (2020) shows that good management allows communities to continue to benefit from marine resources without damaging the environment. However, the main challenge faced is the lack of knowledge and education regarding sustainable practices. Mr. Jefri Haba Rubu highlighted the limited knowledge of the latest cultivation techniques and adequate equipment. With better training and support from the government, sustainable management of marine resources can be more effective, providing long-term benefits for both farmers and the ecosystem.

### 5. Closing

#### 5.1 Conclusion

Based on the results of the research, analysis, and discussion, the following conclusions can be drawn:

1. The sustainability of seaweed cultivation in Raijua District is shaped by a combination of interrelated factors, including environmental conditions, site selection, cultivation technologies, farmer skills and management, market access, government policies, infrastructure, education, and collaborative networks. These elements collectively influence the success and long-term viability of the industry.
2. Seaweed cultivation has been shown to make a substantial contribution to economic growth and community welfare in Raijua District. This impact is evident across social aspects (e.g., improved livelihoods, reduced urbanization, empowerment of women), economic dimensions (e.g., income diversification, microenterprise development), and environmental

sustainability (e.g., ecosystem conservation, carbon absorption, and sustainable marine resource management).

### 5.2 Recommendations

1. **Strengthen Institutional Support:** The government should increase its support through consistent policies, targeted subsidies, infrastructure investment, and training programs aimed at improving farmer capacity and business competitiveness.
2. **Enhance Access to Technology and Innovation:** Stakeholders should facilitate the introduction of modern, adaptive technologies for cultivation and post-harvest processing, which can increase productivity and product quality.
3. **Develop Sustainable Cultivation Guidelines:** A set of environmental guidelines for sustainable seaweed farming should be implemented to ensure ecosystem protection while maintaining high production levels.
4. **Improve Market Access and Value Chains:** Building broader market linkages and supporting local entrepreneurs in value-added processing will increase income and ensure greater economic resilience for coastal communities.
5. **Foster Collaboration and Networking:** Encouraging partnerships among farmers, researchers, local government, and private sector actors will enhance knowledge sharing, innovation adoption, and long-term business sustainability.

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