

SEAWEED AGRIBUSINESS IN A MINING-INFLUENCED REGION: A STUDY OF *EUCHEUMA COTTONII* QUALITY AND MARKETING IN KOLAKA, INDONESIA

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Abstract. In Indonesia's Southeast Sulawesi Province, Kolaka Regency ranks third in *Eucheuma cottonii* seaweed production. Developing *Eucheuma cottonii* agriculture in this region is hampered by the frequent overlap with state-owned and commercial mining operations, which degrades seaweed quality and ultimately impacts the agribusiness chain. This study aims to determine the agribusiness channels for *Eucheuma cottonii* and evaluate the quality of the seaweed grown by local seaweed farmers in Kolaka Regency's mining districts. The study used a qualitative method to identify the agricultural channels and a quantitative method to evaluate the quality of seaweed by laboratory analysis. The findings demonstrate that, on average, the quality of *Eucheuma cottonii* samples collected in mining sites surpasses the threshold limitations established by the Indonesian National Standard (SNI). In these mining regions, seaweed farmers are at the head of the seaweed agribusiness chain, which then moves on to collectors, wholesalers, and processing. This study emphasizes that more mining regulations and increased agricultural productivity are required to preserve seaweed quality and advance sustainability.

Keywords: *Eucheuma cottonii*, Mining-Influenced Region; Seaweed sustainability; Seaweed Agribusiness; Seaweed Quality

1 Introduction

Seaweed cultivation has gained increasing global attention due to its multifaceted roles in food production, ecosystem services, and sustainable aquaculture. As global demand for marine-based resources grows, seaweed aquaculture emerges as a viable and ecologically beneficial solution. Seaweed farming provides high-value products and essential ecosystem services, such as nutrient absorption and carbon sequestration, which contribute to the ecological balance of marine environments [6]. In tropical regions, there is potential for tropical seaweed species to be sustainable food sources while also enhancing biodiversity within cultivation areas [17]. The seaweed industry, particularly the cultivation of *Eucheuma cottonii*, plays a critical role in the economic development of coastal communities across Southeast Asia, including Indonesia. Kolaka Regency is an important part of the nation's carrageenan supply chain, being the third-largest producer of *Eucheuma cottonii* in Southeast Sulawesi Province. However, environmental deterioration brought on by overlapping mining operations—particularly nickel mines—that share coastal zones is posing an increasing threat to this agricultural sector. Mining-related runoff, sedimentation, and possible heavy metal contamination impact seaweed productivity and quality, representing significant risks to marine life and water quality. Numerous studies have shown how mining affects aquatic ecosystems, pointing to changes in salinity, a decrease in water clarity, and the buildup of toxic metals that hinder the establishment of seaweeds and other aquaculture species [10,11]. However, it has been demonstrated that environmental factors such as pollution exposure, water temperature, and nutrient availability significantly impact seaweed quality [9] [14]. Furthermore, Indonesian seaweed marketing and distribution frequently depend on a linear and disjointed

agribusiness chain, which restricts smallholder farmers' financial gains because of their lack of negotiating leverage and reliance on intermediaries [15][8]. Despite the growing focus on sustainable aquaculture and mining consequences, there is still a significant knowledge vacuum about how mining-influenced settings impact *Eucheuma cottonii* quality and marketing dynamics. By combining agribusiness analysis with environmental quality evaluation in a coastal area affected by mining, this study makes a unique contribution by offering an interdisciplinary viewpoint that blends rural economics and marine ecology. This study's primary goals are to (i) evaluate the physical quality of *Eucheuma cottonii* grown in Kolaka Regency's coastal areas that mining operations have impacted and (ii) examine the composition and traits of the regional seaweed agribusiness chain. This study aims to produce data that can inform environmental regulations, strengthen coastal communities, and improve the sustainability of livelihoods based on seaweed. Hypothesis: Because of institutional and external environmental pressures, seaweed (*Eucheuma cottonii*) grown in Kolaka Regency's mining-affected areas satisfies national quality standards and moves through a linear but financially limited agribusiness chain.

2 Research method

In order to thoroughly examine *Eucheuma cottonii* quality and its agriculture marketing channels in Kolaka Regency's mining-influenced areas, this study used a mixed-methods methodology that used quantitative and qualitative techniques.

1. Study Location and Sampling

The study was carried out in coastal regions of Southeast Sulawesi's Kolaka Regency, where mining operations and seaweed farming coexist. Seaweed growers living in Puu Lawulo Village and Sani-Sani Village that were found to be close to or directly impacted by mining operations were chosen using a purposive sample technique. This approach enables researchers to concentrate on particular settings when mining influence is noticeable [4].

2. Quantitative Method – Seaweed Quality Analysis

Eucheuma cottonii samples were gathered from specific farming locations and examined in a qualified laboratory to evaluate the quality of the seaweed. Moisture content, impurity levels, and carrageenan yield were among the parameters examined per the Indonesian National Standard [7]. The quantitative data were subsequently contrasted with these national thresholds to ascertain conformity. Quantitative analysis is crucial for environmental and food quality studies to provide objective, repeatable measures that guide scientific understanding and policy development [1].

3. Qualitative Method – Agribusiness Channel Analysis

Semi-structured interviews with stakeholders, such as seaweed farmers, collectors, distributors, and industrial processors, were conducted to track the seaweed agribusiness chain. This approach sought to determine price schemes, marketing limitations, and product flow. The data underwent thematic analysis to identify trends and connections in the seaweed supply chain [3]. Qualitative interviews make a more profound comprehension of the agricultural system's institutional background and socioeconomic processes possible [5].

4. Data Triangulation

To guarantee the precision and dependability of the results, triangulation was used by cross-validating laboratory results with field observations and interview data [2]. This integrative method aids in capturing the subjective perceptions of participants in the agribusiness network and the quantifiable effects of mining on seaweed quality.

3 Results and discussion

Result

1. Seaweed Quality in Mining-Influenced Areas

The seaweed typically complied with the Indonesian National Standard, according to laboratory analysis of *Eucheuma cottonii* samples taken from coastal farming regions following mining zones in Kolaka Regency [7]. In Sani-Sani Village, the moisture content was 42.05%, whereas in Puu Lawulo Village, it was 36.82%. Puu Lawulo and Sani-Sani registered impurity levels of 3.2% and 4.98%, respectively, below the 5% cutoff and within permissible bounds.

2. Agribusiness Chain Structure

Farmers → collectors → wholesalers, → processing industries are the linear structure of Kolaka's seaweed agribusiness chain. Depending on quality and market demand, farmers usually sell dried seaweed directly to collectors at the village level for rates between Rp 10.000 and Rp 13.000 per kilogram. After that, collectors combine the goods and transport them to agents or wholesalers connected to the processing businesses, most of whom are based in South Sulawesi. The weak negotiating power of seaweed farmers, who sometimes face price instability and rely significantly on intermediaries, is a primary restriction in this chain. Similar circumstances have been documented in other seaweed-producing regions of Indonesia, where the growth of a more equitable value chain is impeded by inadequate infrastructure, a dearth of farmer cooperatives, and asymmetric market knowledge [8].

3. Impact of Mining Activities

Respondents raised concerns regarding the long-term effects of mining operations on seaweed cultivation. Seaweed crops have been shown to develop more slowly and become discolored due to sedimentation from mining runoff. This is consistent with research by Suharno et al. [11], which shows that aquaculture productivity and coastal mining are negatively correlated. Stricter environmental monitoring and cross-sectoral coordination between the mining industry and coastal resource management authorities are necessary to guarantee sustainable seaweed agribusiness. Enhancing the function of local institutions and incorporating seaweed farming into regional spatial planning can also assist in protecting the industry from industrial externalities. [13].

Discussion

The results show that the quality of *Eucheuma cottonii* grown in Kolaka Regency's mining-influenced coastal regions still satisfies and occasionally surpasses the Indonesian National Standard (SNI). This is a noteworthy finding, indicating that seaweed farming methods in the area may still produce high-quality biomass fit for both local and international markets, even in the face of nearby environmentally damaging mining operations. However, mining operations continue to pose a hidden risk to seaweed farming's viability. The quality of coastal water can progressively deteriorate due to mining runoff, mainly when it contains sediments and heavy metals like nickel. Previous research has demonstrated that seaweed growth rates and carrageenan output are adversely affected by exposure to heavy metals and increased sedimentation [10] [11]. Although current seaweed quality appears stable, the long-term ecological risks of mining near aquaculture zones should not be underestimated.

A linear and centralized distribution mechanism, including farmers, collectors, wholesalers, and processing companies, is revealed by the study in terms of the agribusiness chain. This pattern resembles other parts of Indonesia, where small-scale farmers frequently lack access to processing technology, price information, or collective bargaining power [8][15]. As a result, they rely heavily on intermediaries and market volatility, lowering their portion of the seaweed industry's economic benefits. The results highlight the necessity of coordinated governance between managing coastal resources and the mining industry. Mining operations must adhere to coastal zoning laws, and environmental monitoring must be improved by local governments and regulatory agencies. Furthermore, empowering seaweed farmers via community-based businesses or cooperatives may increase their negotiating leverage and advance a more just value chain. This study emphasizes the significance of cross-sectoral policy cooperation to maintain coastal livelihoods in addition to offering technical insights into seaweed quality and marketing channels. It advocates for a more balanced approach to development that balances the ecological and socioeconomic resilience of communities reliant on the sea with commercial endeavors like mining.

4 Conclusion and recommendation

According to the study's findings, *Eucheuma cottonii* grown in Kolaka Regency's coastal areas damaged by mining generally satisfies Indonesian National Standard (SNI) requirements for quality. Seaweed farmers in the area are still able to produce seaweed that is commercially viable in terms of moisture content, impurity levels, and carrageenan production, despite the environmental stresses caused by adjacent mining activities. Farmers, collectors, distributors, and processing firms are all part of Kolaka's traditional seaweed agribusiness chain. This arrangement, however, shows that seaweed farmers have little negotiating strength and are nonetheless susceptible to price swings and market reliance on intermediaries. Even though the seaweed production system as a whole works well, it is not inclusive or resilient, especially when it comes to external environmental challenges like mining. This study emphasizes how important it is to manage coastal resources sustainably and holistically to support seaweed farming's continued success alongside other sectors like mining. The long-term sustainability of Kolaka's seaweed agriculture may be jeopardized without calculated action.

The following suggestions are put forth in light of the study's findings: (1) Increase Environmental Enforcement and Monitoring Mining enterprises close to coastal areas should be subject to stronger environmental rules enforced by local authorities. Regular sedimentation and water quality monitoring should be institutionalized to stop long-term harm to marine ecosystems. (2) Encourage Cooperatives of Seaweed Farmers To increase their market access, fortify pricing discussions, and lessen their reliance on collectors, farmers should be encouraged and assisted in establishing cooperatives or farmer groups. (3) Combine Industrial and Coastal Spatial Planning It is imperative for policymakers to guarantee that spatial planning considers both environmental sustainability and economic development. Aquaculture zones should be carefully defined by coastal zoning laws, which should also restrict industrial encroachment. (4) Make Processing and Market Data More Accessible Giving farmers access to facilities for seaweed drying, grading, and processing together with real-time market data might increase the value of their produce and lessen transaction asymmetries. (5) Promote cooperation amongst many stakeholders. Cooperation between governmental organizations, business leaders, non-governmental organizations, and academic institutions is crucial to creating an inclusive, successful, and ecologically responsible seaweed farming model.

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