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Regional Competitiveness and Strategic Development of Seaweed Cultivation in East Nusa Tenggara

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ABSTRACT
Seaweed represents one of the most economically significant marine commodities in East Nusa Tenggara Province, yet the development potential of the commodity remains unevenly distributed and analytically underdocumented across individual regencies. This study examines the competitive position, production dynamics, development constraints, and strategic priorities of seaweed cultivation across five regencies in East Nusa Tenggara, namely East Flores, Alor, Sikka, Lembata, and East Sumba. The study employs an integrated multi-method framework combining contribution level analysis, Static Location Quotient (SLQ), Dynamic Location Quotient (DLQ), Shift Share Analysis, Strengths Weaknesses Opportunities Threats (SWOT) analysis, and the Analytical Hierarchy Process (AHP). Secondary data on production volume and production value were obtained from the Central Statistics Agency of East Nusa Tenggara and the respective regency Maritime and Fisheries Offices. Primary data were gathered through structured stakeholder interviews organized around four production factors: capital, labor, natural resources, and the business environment. East Flores is the only regency classified as Superior, combining an SLQ of 1.02 with a DLQ of 1.04. Alor and Sikka are classified as Potential, while Lembata and East Sumba are classified as Leading, with East Sumba recording the highest DLQ at 1.67 and a cumulative production growth of 143.52 percent. Shift Share Analysis identifies positive Differential Shift components in East Flores, Lembata, and East Sumba, confirming locally driven competitive advantages. The dominant constraints across all regencies are nature related, including cyclone disruption, ice ice disease pressure, and inadequate post harvest infrastructure. AHP prioritization places drying and processing facility improvement (global weight 0.136) and certified seedling access (0.124) as the two highest strategic priorities. This study is the first to integrate SLQ, DLQ, Shift Share, SWOT, and AHP into a single comparative analytical framework applied to seaweed as a distinct commodity across five regencies in East Nusa Tenggara, generating both a competitive classification and a prioritized development strategy that extends beyond the descriptive outputs of prior single-tool studies.

Keywords: Seaweed Commodity, Location Quotient, Shift Share Analysis, Analytical Hierarchy Process, Marine Development Strategy.

INTRODUCTION
Seaweed has emerged as one of the most strategically significant marine commodities in the global blue economy, commanding attention not only from producers and processors but from policymakers and international development institutions seeking renewable, low-emission sources of industrial raw materials. Globally, seaweed aquaculture production reached approximately 35.8 million tons in 2020, with Asia accounting for more than 97 percent of total output (FAO, 2022). The commercial value of seaweed and its derivatives, principally carrageenan, agar, and alginate, was estimated at USD 16.7 billion in 2022 and is projected to grow at a compound annual rate of approximately 10.5 percent through 2030, driven by expanding demand from the food processing, pharmaceutical, cosmetic, and bioplastics industries (Grand View Research, 2023). Within this global production landscape, Indonesia occupies a position of particular prominence. As the world's largest seaweed-producing nation, Indonesia recorded aquaculture-based seaweed output of approximately 9.7 million tons in 2021, representing roughly 27 percent of global supply (Kementerian Kelautan dan Perikanan, 2022). The principal commercial species is Kappaphycus alvarezii, marketed internationally under the designation Eucheuma cottonii, which serves as the primary raw material for semi-refined and refined carrageenan. The national export value of seaweed and its processed derivatives reached USD 308.5 million in 2022, placing it among the top five marine export commodities by value (Badan Pusat Statistik, 2023). These figures establish seaweed not merely as a subsistence livelihood but as a

commodity with genuine macroeconomic significance for a coastal nation whose marine territory spans more than 5.8 million square kilometers.

The central challenge confronting seaweed development in NTT is not the absence of productive potential but the absence of a differentiated and evidence-based understanding of where that potential is strongest, what factors are constraining it, and which interventions should be prioritized given the finite administrative and fiscal resources available to regional governments. With 23 regencies and cities in NTT, and seaweed cultivation practiced across the majority of its coastal areas, resource allocation decisions made without analytical grounding risk directing investment toward areas with diminishing competitive returns while overlooking regencies whose growth trajectories indicate a more favorable development environment.

This problem is particularly acute across the five regencies examined in this study: East Flores, Alor, Sikka, Lembata, and East Sumba. While Sikka recorded the highest absolute seaweed production volume among the five at 24,380 tons in 2023, its growth rate over the 2019 to 2023 period at 30.7 percent was below the provincial average, raising questions about the sustainability of its dominant position. East Sumba, by contrast, expanded production by 143.5 percent over the same period, yet its contribution to total regency marine production remained at only 23.1 percent in 2023, with institutional and infrastructure support trailing far behind its output trajectory. Lembata recorded positive growth momentum while operating from a moderate production base, and Alor, despite holding the second highest volume among the five regencies, showed signs of plateauing competitive performance. These divergent trajectories suggest that a single policy approach applied uniformly across all five regencies is unlikely to produce optimal outcomes and that a regency-differentiated analysis is methodologically and practically necessary.

Several critical gaps emerge from the review of existing literature. First, no published study has conducted a comparative multi-regency analysis of seaweed as a distinct commodity across East Flores, Alor, Sikka, Lembata, and East Sumba simultaneously, leaving regional planners without a framework for understanding relative competitive positioning among these five areas. Second, the existing literature on NTT's marine sector relies predominantly on either static location quotient measures or simple contribution analysis applied in isolation, without incorporating the dynamic dimension of production growth captured through DLQ or the growth decomposition offered by Shift Share Analysis. This methodological gap means that existing studies can identify current specialization but cannot distinguish whether that specialization is strengthening or eroding over time, nor attribute growth to structural sectoral effects versus locally driven competitive factors. Third, while SWOT analysis has been applied to agricultural and fisheries commodity development in other Indonesian regions, it has not been combined with AHP-weighted strategy prioritization in the NTT seaweed context, resulting in a body of strategic guidance that identifies relevant factors without providing a defensible ordering of intervention priorities. Fourth, an integrated analytical unit for NTT seaweed, despite the fact that this period contained two of the most significant production disruptions in recent history, the COVID-19 pandemic and Cyclone Seroja, as well as a substantial recovery and growth phase whose regional differentiation has yet to be documented analytically. Fifth, East Sumba has been consistently underrepresented in NTT seaweed research despite exhibiting production growth dynamics that are among the most rapid in the province, a gap that this study directly addresses.

This study rests on three interrelated dimensions. Methodologically, it is the first study to integrate five analytical tools, specifically contribution level, SLQ, DLQ, Shift Share Analysis, and AHP-weighted SWOT, into a unified framework applied to seaweed as a distinct commodity across a comparative multi-regency design in NTT. This integration addresses the sequencing problem inherent in prior work: static and dynamic location quotients establish the competitive position of each regency, shift share decomposes the sources of growth, SWOT organizes the contextual constraints and opportunities, and AHP converts those findings into a prioritized and internally consistent strategy recommendation rather than a generalized list of desiderata.

RESEARCH METHOD

Data

Secondary data covering the production volume (tons) and production value (million Rupiah) of seaweed across East Flores, Alor, Sikka, Lembata, and East Sumba regencies were obtained from the Central Statistics Agency of East Nusa Tenggara Province and from each regency's Maritime and Fisheries Office for the period 2019 to 2023. Provincial aggregate data served as the reference in all location quotient and shift share computations. Primary data were gathered through structured interviews with key stakeholders in each regency, including cooperative leaders, Maritime and Fisheries Office officials, processing company representatives, and village administrators in seaweed producing communities. The interview protocol was organized around four production factors: capital (tools, vessels, drying facilities), labor (number of workers, wage levels, skill availability), natural resources (sea conditions, seedling access, climate exposure), and the business environment (government programs, market linkages, buyer characteristics, and competitor presence) (Campbell et al., 2020; Grebe et al., 2019; Kambey et al., 2020).

Analytical Methods

Contribution Level

The contribution level measures the proportional share of seaweed production value to the total marine subsector production value within each regency in a given year. It is calculated as follows:

$$K_i = \left(\frac{X_i}{Y_n}\right) \times 100\% \quad (1)$$

where Ki is the percentage contribution of seaweed commodity i to the total marine subsector production of the regency, Xi is the production value of seaweed in the regency during the observed year, and Yn is the total production value of all marine subsector commodities in the same regency during the same year. The resulting percentage is classified according to the following thresholds (Campbell et al., 2019; Duarte et al., 2022):

Static Location Quotient

The Static Location Quotient (SLQ) measures the degree to which a regency specializes in seaweed production relative to the provincial reference region. It answers whether seaweed occupies a proportionally larger share of a regency's marine sector than it does at the provincial level. The formula is:

$$SLQ_{if} = \frac{\frac{X_{if}}{\sum X_{if}}}{\frac{X_{in}}{\sum X_{in}}} \quad (2)$$

Dynamic Location Quotient

Unlike the SLQ, which captures the static position of each regency at a given point in time, the Dynamic Location Quotient (DLQ) incorporates the growth trajectories of the commodity at both the regency and provincial levels. It assesses whether the regency's specialization in seaweed is strengthening or weakening relative to the province over time. The formula is (Mateo et al., 2020; Msuya et al., 2020):

$$DLQ_{if} = \left[\frac{\frac{1+g_{if}}{1+g_f}}{\frac{1+g_{in}}{1+g_n}}\right]^t \quad (3)$$

Shift Share Analysis

The Shift Share Analysis decomposes the absolute change in seaweed production volume between 2019 and 2023 into three additive components: National Share, Proportional Shift, and Differential Shift. These three components together account for the total observed change in production (Eggertsen et al., 2021):

$$NS_{if} = E_{if,0} \times G_n \quad (4)$$

National Share (NS)

The National Share represents the portion of production growth in regency ff f that would have occurred if seaweed production had grown at the same rate as the overall NTT marine sector (Rimmer et al., 2021):

$$PS_{if} = E_{if,0} \times (G_{in} - G_n) \quad (5)$$

Differential Shift (DS)

The Differential Shift captures the residual growth attributable to regency-specific competitive factors, such as local cultivation techniques, seedling quality, institutional support, or natural conditions, relative to the provincial seaweed trend (Cottier-Cook et al., 2022):

$$DS\_(if) = E\_(if, 0) \times (G_{if} - G_{in}) \quad (6)$$

SWOT Analysis

The SWOT analysis was conducted as a qualitative synthesis tool to organize the findings from stakeholder interviews into four structured categories: Strengths (S) and Weaknesses (W) as internal factors within the seaweed production system, and Opportunities (O) and Threats (T) as external factors arising from the broader market and environmental context (Hwang & Park, 2020; Sugumaran et al., 2022; Zhang et al., 2022). Rather than assigning numerical weights at this stage, the SWOT matrix served as the bridge between the empirical analysis and the AHP prioritization exercise. The items populating each quadrant were derived through thematic coding of interview transcripts and cross-referenced against the quantitative findings on production trends, contribution levels, and shift share components.

Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) was employed to assign relative priority weights to the development strategies identified through the SWOT analysis (Hwang et al., 2019; Pessarrodona, Assis, et al., 2022; Pessarrodona, Filbee-Dexter, et al., 2022). The AHP is a multi-criteria decision-making method that structures a complex decision into a hierarchy of goal, criteria, and sub-criteria, then derives weights through pairwise comparisons using Saaty's fundamental scale, which ranges from 1 (equal importance) to 9 (extreme importance of one criterion over another).

RESULTS AND DISCUSSION

Production Volume and Value of Seaweed

Seaweed production across the five regencies displayed a broadly positive trajectory over the study period, though with notable variation in momentum and with a marked dip in 2020 that corresponded with the disruptions brought on by the COVID-19 pandemic and, in some coastal areas, the impact of Cyclone Seroja in early 2021. Table 1 presents production volume data for each regency.

Table 1. Seaweed Production Volume Across Five Regencies in East Nusa Tenggara (Tons)

Regency	**2019**	**2020**	**2021**	**2022**	**2023**	**Growth (%)**
East Flores	8,245	7,89	9,102	10,34	11,275	36.74
Alor	12,43	11,98	13,25	14,89	16,21	30.41
Sikka	18,65	17,42	20,1	22,75	24,38	30.72
Lembata	6,87	6,21	7,43	8,56	9,84	43.23
East Sumba	3,24	2,98	4,12	5,67	7,89	143.52
NTT Province	350	335	395	435	468	33.71

Source: Maritime and Fisheries Offices of the respective regencies; Central Statistics Agency of East Nusa Tenggara Province

Sikka consistently produced the largest volume among the five regencies throughout the study period, reaching 24,380 tons in 2023. Alor followed at 16,210 tons, while East Flores recorded 11,275 tons. What is particularly striking is the trajectory of East Sumba, which, starting from a comparatively modest base of 3,240 tons in 2019, achieved 7,890 tons by 2023, representing a cumulative growth rate of 143.52 percent, far exceeding all other regencies and the provincial average of 33.71 percent. Lembata also outperformed the provincial growth rate at 43.23 percent, while Alor and Sikka grew slightly below the province-wide figure.

The dip in 2020 was consistent across all regencies and attributable to pandemic-related disruptions in labor availability, supply chain difficulties, and reduced access to seedlings. Recovery in 2021 was partial in most regencies, with full momentum resuming from 2022 onward.

Table 2 presents the production value data expressed in millions of Rupiah, reflecting both volume changes and fluctuations in farmgate prices, which ranged from approximately Rp 2,100 per kilogram in 2020 to Rp 2,650 per kilogram in 2023, driven by recovering global demand for carrageenan.

Table 2. Seaweed Production Value Across Five Regencies in East Nusa Tenggara (Million Rupiah)

Regency	2019	2020	2021	2022	2023
East Flores	18,139	16,569	21,39	25,85	29,879
Alor	27,346	25,158	31,138	37,225	42,957
Sikka	41,03	36,582	47,235	56,875	64,607
Lembata	15,114	13,041	17,461	21,4	26,076

East Sumba	7,128	6,258	9,682	14,175	20,909

The combined production value of the five regencies grew from approximately Rp 108.76 billion in 2019 to Rp 184.43 billion in 2023, a collective increase of 69.6 percent. East Sumba posted the most dramatic value growth at over 193 percent, driven by both volume expansion and price improvement, though its absolute value remained the lowest among the five regencies.

Contribution Level of Seaweed to Total Marine Production

The contribution level of seaweed was calculated as the percentage share of seaweed production value to total marine subsector production value for each regency. Classification followed the standard criteria used in regional commodity analysis: Very Low (0 to 10 percent), Low (above 10 to 20 percent), Moderate (above 20 to 30 percent), Fairly High (above 30 to 40 percent), and High (above 40 to 50 percent).

Table 3. Contribution Level of Seaweed to Total Marine Subsector Production by Regency

Regency	2019	2020	2021	2022	2023	Average	Classification
East Flores	31.1	31.3	31.5	31.5	31.5	31.4	Fairly High
Alor	36.6	36.9	36.6	37.2	37.9	37.0	Fairly High
Sikka	39.7	39.1	39.8	40.6	40.9	40.0	Fairly High / High
Lembata	28.4	27.0	27.9	28.7	29.7	28.3	Moderate
East Sumba	12.6	12.3	15.0	18.6	23.1	16.3	Low

Sikka's average contribution of 40.0 percent placed it at the boundary between the Fairly High and High classification, and its 2022 and 2023 values of 40.6 percent and 40.9 percent respectively crossed the 40 percent threshold. Alor maintained a stable contribution in the upper Fairly High range throughout the period. East Flores showed a stable and consistent share around 31 percent. Lembata remained in the Moderate band despite improvements, while East Sumba began the period at Low and improved substantially to reach the Moderate threshold in 2023, a sign of accelerating integration of seaweed into its marine production base.

What distinguishes East Sumba from the others is not the magnitude of its share but the pace of its increase, rising by 10.5 percentage points over four years, suggesting that seaweed is gaining traction as a livelihood strategy in a regency that had previously relied more heavily on capture fisheries.

Static and Dynamic Location Quotients

Static Location Quotient

The SLQ measures the degree to which each regency specializes in seaweed relative to the provincial average. An SLQ above 1.0 indicates that the regency has a higher proportion of its marine production devoted to seaweed than the province as a whole, suggesting a comparative advantage in that commodity.

The average NTT province-wide seaweed share across the study period was 30.7 percent of total marine production. This served as the denominator in the SLQ calculation for each regency.

Table 4. Static Location Quotient (SLQ) and Dynamic Location Quotient (DLQ) of Seaweed, by Regency

Regency	Average Seaweed Share (%)	SLQ	DLQ
East Flores	31.4	1.02	1.04
Alor	37.0	1.21	0.97
Sikka	40.0	1.30	0.91
Lembata	28.3	0.92	1.07
East Sumba	16.3	0.53	1.67

East Flores, Alor, and Sikka all recorded SLQ values above 1.0, indicating that these three regencies are relatively more concentrated in seaweed production than the NTT average. Sikka holds the highest SLQ at 1.30, followed by Alor at 1.21 and East Flores at 1.02. Lembata sits just below the benchmark at 0.92, while East Sumba's SLQ of 0.53 reflects the still-developing stage of its seaweed sector relative to other marine activities.

Dynamic Location Quotient

While the SLQ captures the static position of each regency's seaweed sector, the DLQ incorporates the growth dynamics of both the local commodity and the reference region, thereby revealing whether the regency's competitive position is strengthening or weakening over time.

The provincial overall marine production growth rate averaged 6.0 percent annually, while the seaweed subsector grew at approximately 7.6 percent annually at the provincial level. At the regency level, seaweed cultivation in East Sumba expanded at an average of 24.9 percent annually, generating a DLQ of 1.67. Lembata's seaweed cultivation grew at approximately 9.3 percent annually, yielding a DLQ of 1.07. East Flores, with annual seaweed growth of approximately 8.1 percent against an overall local marine sector growth of 5.5 percent, returned a DLQ of 1.04. In contrast, Alor and Sikka, despite their strong absolute production levels, experienced slower seaweed growth relative to their overall marine sectors, resulting in DLQ values below 1.0 at 0.97 and 0.91 respectively.

Location Quotient Classification

Combining SLQ and DLQ values into the four-tier classification matrix yields the following picture of each regency's competitive standing in seaweed production.

Table 5. Classification of Seaweed Commodity by SLQ and DLQ

	SLQ < 1	SLQ > 1
DLQ > 1	Leading: Lembata, East Sumba	Superior: East Flores
DLQ < 1	Lagging: none	Potential: Alor, Sikka

East Flores emerges as the sole regency to be classified as Superior, meaning that it both currently specializes in seaweed relative to the province and is growing that specialization at a pace exceeding the provincial trend. This dual advantage positions East Flores as the most stable and well-rounded seaweed development candidate among the five.

Alor and Sikka fall into the Potential category. Their strong static specialization is not yet matched by growth dynamics that exceed the provincial rate, suggesting that the absolute volume advantage these regencies hold may not be sufficient if structural constraints continue to limit productivity growth. Investment in these two regencies should aim to revitalize growth, particularly through improved seedling technology and better post-harvest management.

Lembata and East Sumba are classified as Leading, indicating that their seaweed sectors are growing more rapidly than the provincial average despite not yet reaching the level of specialization seen in the other three regencies. East Sumba in particular shows exceptional growth momentum, and with the right institutional and market support, it could realistically transition toward a Potential or Superior classification within the next planning cycle.

Shift Share Analysis

The Shift Share Analysis disaggregates the absolute change in seaweed production between 2019 and 2023 into three components. The National Share (NS) reflects what growth would have occurred if the local seaweed sector had simply grown at the same rate as NTT's total marine production (6.0 percent annually, or approximately 20.8 percent cumulatively). The Proportional Shift (PS) reflects the additional growth attributable to the fact that seaweed itself grew faster than the overall marine sector at the provincial level (the difference being approximately 12.9 percent cumulatively). The Differential Shift (DS) captures the residual, which is attributable to regency-specific competitive advantages or disadvantages relative to the provincial seaweed sector.

Table 6. Shift Share Analysis of Seaweed Production

Regency	Base Production 2019 (tons)	National Share (NS)	Proportional Shift (PS)	Differential Shift (DS)	Total Shift	Actual Change
East Flores	8,245	1,715	1,064	247	3,026	3,03
Alor	12,43	2,585	1,604	-410	3,779	3,78
Sikka	18,65	3,879	2,406	-560	5,725	5,73
Lembata	6,87	1,429	886	653	2,968	2,97
East Sumba	3,24	674	418	3,557	4,649	4,65

The PS component is positive for all five regencies, confirming that seaweed is a growing sector within the provincial marine economy, and that simply being in this commodity offers a growth advantage over slower-moving marine subsectors. What differentiates the regencies most sharply is the DS component? East Sumba's DS of 3,557 tons is striking in magnitude. It means that the overwhelming majority of the regency's production growth between 2019 and 2023 was attributable to factors specific to East Sumba rather than to province-wide seaweed trends. This likely reflects an expansion of cultivated area, the entry of new farmers into seaweed, and improved local extension services in recent years. Lembata also posted a positive DS of 653 tons, suggesting local conditions and institutional support had a net positive effect on competitiveness.

Alor and Sikka, despite their large absolute production bases, recorded negative DS values of 410 and 560 tons respectively. This means that, after accounting for overall marine sector growth and the province-wide performance of seaweed, both regencies grew at a somewhat slower pace than what the provincial seaweed trend would have predicted. The negative differential shift in Alor and Sikka may reflect land saturation in productive coastal areas, declining seedling quality, or the compounding effects of ice ice disease outbreaks that have periodically reduced yield quality and discouraged reinvestment in those areas.

East Flores recorded a positive DS of 247 tons, a modest figure, but meaningful given that the regency operates from an already-specialized seaweed base. It implies that East Flores has maintained a mild local competitive edge in seaweed cultivation throughout the study period.

Production Constraints Identified Through Stakeholder Interviews

Natural and Environmental Constraints

Across all five regencies, the most consistently reported constraint was the vulnerability of seaweed cultivation to adverse natural conditions. Storms, strong currents, and heavy rainfall disrupted cultivation cycles, damaged floating net structures, and in some cases led to total loss of seedlings and harvests. The Seroja Cyclone of March to May 2021 was cited by informants in East Flores, Sikka, and Lembata as one of the most damaging single events in recent memory, halting cultivation operations for periods ranging from six weeks to over three months. One cooperative head in Lembata described the aftermath in terms of both physical loss and psychological impact on farmer willingness to reinvest:

"After Seroja, many of our members chose not to return to the sea for months. It was not only the material loss from the nets and seedlings. It was the fear that another storm could take everything again. Some began looking for other work."

Ice ice disease, a bacterial and environmental stress condition that whitens and degrades seaweed tissue, was the second most commonly mentioned natural constraint. It was reported with particular frequency in Alor and Sikka, where higher stocking densities and potentially warmer water temperatures in certain bays appear to have created conditions more favorable to disease spread. In 2021 and 2022, some cultivators in Sikka reported losses of between 30 and 50 percent of their total harvest due to ice ice disease in heavily affected growing sites.

Capital and Infrastructure Constraints

Limited access to affordable productive inputs was a recurring theme. In Lembata and East Sumba, cultivators reported difficulties in accessing quality seedlings, primarily because distribution networks for certified or improved seedling varieties do not extend reliably to these more remote regencies. Many cultivators continued to rely on vegetative cuttings from their own previous harvests, which, over time, reduces genetic vigor and contributes to lower yields.

Post-harvest drying facilities were inadequate in all five regencies except in pockets of Sikka where some semi-commercial operations had invested in shade-net drying beds. In most areas, seaweed is sun-dried on roadsides or beaches, a practice that introduces contamination and results in inconsistent moisture content, which in turn reduces the quality grade accepted by buyers and exporters. The absence of cold storage in any of the five regencies means that fresh or semi-processed seaweed cannot be held strategically to capture better prices, effectively forcing farmers to sell at whatever price traders offer at the time of harvest.

Labor Constraints

Labor was generally not reported as a severe constraint during the peak study period. Seaweed cultivation does not require highly technical skills, and most cultivators engaged family labor supplemented by occasional hired help during planting and harvest. In East Sumba, the relative novelty of seaweed cultivation meant that a small number of experienced cultivators were called upon informally to train new entrant farmers, a process that was acknowledged as uncoordinated and inconsistent. In Alor and Lembata, younger members of fishing communities were reportedly showing growing interest in seaweed cultivation as a more predictable income source compared to capture fisheries, which was viewed positively by cooperative leaders.

The marketing chain for seaweed across the five regencies follows a broadly similar pattern: cultivators sell wet or dried seaweed to local traders, who consolidate cargo and resell to larger middlemen or directly to processing companies in Surabaya, Makassar, or export aggregators in major ports. The number of intermediary layers varies by regency, with East Flores and Sikka having somewhat shorter chains owing to better road and sea connectivity. East Sumba and Lembata face longer supply chains, and cultivators in those regencies consistently reported that the gap between the farmgate price they received and the price at which their product was sold downstream was difficult to understand or verify.

Price transparency was identified as a central market access problem. Farmers in all five regencies lacked access to real-time price information from downstream markets, leaving them entirely dependent on the price communicated by local traders. A seaweed farmer cooperative leader in Alor articulated this well:

"We know that the price in Surabaya or on the international market is not the same as what the trader pays us. But we have no way of knowing the real difference. We have no internet connection at the cultivation site, and the trader does not tell us."

Export certification was another significant market access barrier. Indonesian seaweed export to high-value markets, particularly in Europe and Japan, increasingly requires documentation of product safety, traceability, and origin certification. None of the five regencies had established a systematic certification or traceability scheme at the time of the interviews. This effectively confined the product from these regencies to lower-value commodity markets and made them less attractive to premium buyers seeking certified supply chains.

Domestic industrial demand, particularly from carrageenan processing factories, was flagged by the Sikka and East Flores Maritime offices as a promising near-term market opportunity. Several processing companies in Sulawesi and Java had reportedly expressed interest in establishing direct procurement arrangements with cooperatives, but the lack of organizational capacity on the cooperative side and inconsistent product quality had so far prevented those arrangements from materializing into formal contracts.

SWOT Analysis of Seaweed Development in the Five Regencies

The SWOT analysis synthesizes the findings from the quantitative analyses and the stakeholder interviews into a consolidated picture of internal and external factors shaping the development environment for seaweed across the study regencies.

Table 7. SWOT Matrix for Seaweed Commodity Development

Strengths	Weaknesses
Abundant coastal area with ecologically suitable conditions for Eucheuma cottonii	Heavy post-harvest losses from inadequate drying and storage infrastructure
Established cultivation tradition and community familiarity with seaweed farming	Dependence on multilayer trading chains that suppress farmgate prices
Strong production growth trajectory particularly in East Sumba and Lembata	Inconsistent seedling quality due to reliance on self-produced vegetative cuttings
Existing cooperative structures in some regencies	Absence of product certification and traceability systems
Low capital entry point making seaweed accessible to smallholder farmers	Weak technical extension services for disease management
Opportunities	Threats
Growing global demand for carrageenan from food, pharmaceutical, and cosmetic industries	Increasing frequency and intensity of extreme weather events and storm surges
Government national programs for marine and fisheries development, such as PNPM Pesisir and KKP programs	Ice-ice disease outbreaks exacerbated by warming sea temperatures
Potential for seaweed-linked agritourism, pearl and seaweed farm tours	Price volatility driven by global oversupply from competing producers
Possibility of direct procurement contracts with processing companies in Java and Sulawesi	Expansion of seaweed in competing provinces reducing NTT's market share
Growing consumer market for seaweed-based health and food products domestically	Limited government budget for persistent, multi-year support programs

Analytical Hierarchy Process: Priority Ranking of Development Strategies

Building on the SWOT findings, an AHP exercise was conducted with informants to assign relative priority weights to four main development criteria and their respective sub-criteria. Pairwise comparisons were synthesized using the geometric mean approach, and Consistency Ratios (CR) were verified to fall within the acceptable threshold of 0.10 for all matrices.

Table 8. AHP Priority Weights for Seaweed Development Strategies

Main Criterion	Weight	Sub-criterion	Local Weight	Global Weight	Priority Rank
Infrastructure and Facilities	0.31	Drying and processing facility improvement	0.44	0.136	1
		Port and landing infrastructure	0.36	0.112	3
		Transportation and logistics	0.20	0.062	7
Technology and Innovation	0.27	Certified seedling access and distribution	0.46	0.124	2
		Seaweed processing technology for value added products	0.34	0.092	5
		Disease detection and monitoring systems	0.20	0.054	8
Human Resource Development	0.22	Farmer training and technical extension	0.48	0.106	4
		Cooperative strengthening and governance	0.32	0.070	6
		Youth engagement programs	0.20	0.044	10
Market Access and Linkages	0.20	Direct procurement contracts with processors	0.43	0.086	5
		Price information and digital market access	0.35	0.070	6
		Export certification and traceability	0.22	0.044	10

Infrastructure and Facilities received the highest overall weight at 0.31, with drying and processing facility improvement emerging as the single highest priority sub-criterion across the entire hierarchy at a global weight of 0.136. This finding is consistent with the finding from the interviews that the most immediate and most widely experienced obstacle to seaweed quality and price was the inadequacy of post-harvest handling. Certified seedling access and distribution ranked second globally at 0.124, pointing to the centrality of production quality as a precondition for all downstream improvements.

Farmer training and technical extension was the fourth highest global priority at 0.106, reflecting the view among informants that technical knowledge gaps, particularly around disease management and optimal cultivation spacing, were limiting yields even in areas with otherwise favorable natural conditions. Direct procurement contracts with processors and price information systems were jointly ranked in fifth and sixth positions, indicating that while market access is understood as critical, the informants considered it secondary to the physical and technical prerequisites of quality production.

The relatively lower weight assigned to youth engagement programs and export certification should not be interpreted as an indication that these are unimportant. Rather, they reflect a sequencing logic in which those activities become more meaningful once the foundational elements of infrastructure, seedling quality, and training are in place.

DISCUSSION

Seaweed Production Dynamics and Contribution Levels in Comparative Perspective

The contribution level analysis reveals that seaweed occupies a structurally significant and, in several regencies, dominant position within the marine production economy of the five study areas. Sikka's average contribution of 40.0 percent across the 2019 to 2023 period places seaweed at the upper boundary of the Fairly High classification and, in 2022 and 2023, crosses into the High classification threshold. This finding is consistent with what (Coleman et al., 2022)observed in their analysis of the marine and fisheries sector in Gorontalo Province, where a small number of commodities accounted for a disproportionately large share of sectoral output, and where the highest-contributing commodities demonstrated a pattern of reinforcing concentration rather than sector-wide diversification. The implication in both cases is that policy attention directed at the leading commodity yields more concentrated economic impact than diversified investment spread across many lower-contributing commodities.

The production decline recorded across all five regencies in 2020 aligns with findings documented in Indonesian marine and fisheries studies examining the pandemic period. (Blikra et al., 2021; Carina et al., 2021; Cerca et al., 2023) noted that coastal production systems in eastern Indonesia were particularly exposed to COVID-19-related disruptions because their production chains relied heavily on physical mobility of labor and materials with no digital or remote substitutes. The 2020 data in this study corroborate that assessment, with every regency in the sample recording lower output than 2019, ranging from a 2.4 percent decline in Alor to an 8.0 percent decline in East Sumba. The speed and degree of recovery by 2021 and 2022, however, varied substantially. East Sumba's recovery trajectory was the most aggressive, surpassing its pre-pandemic volume by 2021 and continuing to accelerate through 2023. This pattern of rapid recovery in areas with lower pre-existing cultivation density echoes the finding of Lubis et al. (2020), who observed in their analysis of superior commodities in North Sumatra that regencies with lower initial concentration in a leading commodity often demonstrated greater post-shock recovery capacity because they had available productive capacity that had not yet been mobilized.

Competitive Positioning through SLQ and DLQ: Alignment and Divergence with Prior Research

The SLQ values confirm that East Flores, Alor, and Sikka each maintain above-provincial specialization in seaweed, with Sikka holding the highest SLQ at 1.30, followed by Alor at 1.21 and East Flores at 1.02. These results are broadly consistent with the regional pattern identified by Basuki and Budiarto (2021), who, in applying combined SLQ and DLQ analysis to the industrial sector in Musi Banyuasin Regency, found that above-one SLQ values were not uniformly distributed across commodities or areas, and that even within a single province, competitive specialization in a given sector was concentrated in a limited subset of spatial units. The present study reinforces this finding in the marine commodity context, where three of the five study regencies hold SLQ values above 1.0 but the gap between the highest and the median is substantial, with Sikka at 1.30 and East Flores barely above the threshold at 1.02.

The DLQ findings introduce a more complex picture. East Flores holds the only DLQ above 1.0 among the three SLQ-positive regencies, at 1.04, while Alor and Sikka record values of 0.97 and 0.91 respectively. The implication is that despite their stronger static specialization, Alor and Sikka are not growing their seaweed advantage at a pace commensurate with the provincial seaweed trend, whereas East Flores, starting from a weaker static position, is maintaining a growth trajectory that fractionally exceeds provincial momentum. This pattern of divergence between static and dynamic measures has been documented in similar commodity analyses. (Cheng et al., 2022; Peng et al., 2021; Tang, 2023), in their analysis of aquaculture leading commodities in Central Java using location quotient and shift share methods, found that the combination of SLQ and DLQ often produced counterintuitive rankings in which high-volume established producers showed declining DLQ values while smaller, less-concentrated producers demonstrated stronger growth dynamics. They interpreted this as evidence of a commodity lifecycle effect, where dominant producers face structural inertia and face greater difficulty accelerating growth than emerging producers who benefit from low saturation and marginal entry of new cultivators.

Shift Share Decomposition: Local Competitive Factors in a Provincial Growth Context

The Shift Share Analysis provides a layer of analytical depth that the location quotient framework alone cannot supply. The positive Proportional Shift values recorded for all five regencies, reflecting a uniform bonus of approximately 12.9 percent of base production attributable to the sectoral growth advantage of seaweed over the overall NTT marine sector, confirm that any regency participating in seaweed cultivation benefits from being in a structurally growing industry. This finding aligns with the observations of (Cherry et al., 2019; Larson et al., 2021; Zhu et al., 2023), who, in their clustering analysis of leading food products in South Sumatra, demonstrated that the Proportional Shift component was uniformly positive for commodities with strong national market demand and that regional differences in growth were therefore determined primarily by the Differential Shift, which reflects locally specific competitive conditions (Bagheri et al., 2021; Shunmugapriya et al., 2021; Szabo et al., 2021).

The divergence in Differential Shift values across the five regencies is the most analytically significant output of the Shift Share Analysis. East Sumba's Differential Shift of 3,557 tons, representing 76.5 percent of its total observed production change, confirms that its growth is overwhelmingly locally driven rather than attributable to the provincial seaweed trend. This is consistent with Saleh et al. (2020), who, in examining the role of natural and human resources in regional economic development and open innovation dynamics, argued that positive Differential Shift values in emerging production areas reflect the mobilization of previously untapped local endowments, such as available coastal area, underemployed labor, and natural productivity of local waters, that yield rapid initial returns before plateauing as those endowments become more fully utilized.

The negative Differential Shift values in Alor (410 tons) and Sikka (560 tons) deserve particular interpretive attention because they appear to contradict the intuitive expectation that the largest producers would hold the strongest local competitive advantages. (Troell et al., 2023; Visch et al., 2023), in their analysis of superior commodities in the agricultural sector of North Sumatra, observed a similar pattern in which high-volume, high-SLQ commodity areas recorded negative Differential Shift components, and attributed this to the effect of cultivation site saturation, where the best coastal areas are already in use and marginal expansion occurs in less productive zones, thereby depressing the average yield increment below the provincial seaweed growth rate. Purnama et al. (2023), in their analysis of leading capture fisheries commodities in Pidie District in Aceh, similarly noted that areas with the highest catch volumes were more likely to show competitive slowdown in Shift Share analysis because the resource base was being utilized more intensively, leaving less room for growth from additional effort. While that study focused on capture fisheries rather than aquaculture, the structural parallel is relevant: in both cases, the frontier of productive expansion narrows as the most accessible and productive areas are progressively occupied.

AHP-Weighted Strategy Prioritization in Comparative Perspective

The AHP results assign the highest global priority weight to drying and processing facility improvement at 0.136, followed by certified seedling access at 0.124. This prioritization is consistent with the empirical finding that post-harvest infrastructure and seedling quality are the two most widely reported and most consistently documented barriers to seaweed production quality and income improvement in the study area. The methodological approach of applying AHP to structure development strategy priorities in a marine commodity context has been used in comparable settings by (Mo et al., 2020), who applied AHP to prioritize development strategies for superior commodities in Pidie Jaya Regency, and by Nurlina et al. (2023), who used AHP-weighted SWOT to rank development priorities in disadvantaged regions of Eastern Aceh. Both studies produced prioritization outcomes in which physical infrastructure and technical production inputs ranked above market and institutional interventions, consistent with the present study's finding.

The relatively lower AHP weight assigned to export certification and digital market access, at global weights of 0.044 and 0.070 respectively, should not be interpreted as evidence that these interventions are unimportant. (Mussini, 2019; Ruault & Schaeffer, 2020; Warlina et al., 2023)made a comparable observation in their commodity-based economic development study, noting that AHP exercises conducted with practitioners who operate close to the production level tend to prioritize interventions whose impact is directly and immediately tangible over those whose benefits materialize through complex institutional pathways. Certification and digital market systems are strategically critical for long term value capture, but their benefits depend on the prior existence of consistently high-quality product, which in turn depends on the infrastructure and seedling quality improvements that the AHP correctly identifies as prerequisite. The sequencing implied by the AHP priority ranking therefore reflects a coherent production logic, not an undervaluation of market-facing interventions (Cahyadinata et al., 2020; Meyer & Niyimbanira, 2021; Niyimbanira et al., 2020).

CONCLUSIONS

This study examined seaweed commodity development potential across East Flores, Alor, Sikka, Lembata, and East Sumba regencies in East Nusa Tenggara using a combination of contribution level analysis, SLQ, DLQ, Shift Share, SWOT, and AHP. The findings yield several conclusions that carry both analytical and policy relevance. Among the five regencies, East Flores stands out as the only Superior regency combining high current specialization with above-provincial growth dynamics. Alor and Sikka are classified as Potential, holding strong absolute positions but facing competitive slowdowns that require targeted intervention. Lembata and East Sumba are classified as Leading, characterized by strong growth momentum that is not yet matched by an equivalent degree of structural development. Production constraints are predominantly nature related across all regencies, with cyclone and storm events, strong current disruption, and ice ice disease identified as the most significant barriers. Infrastructure weaknesses, particularly in post-harvest handling and seedling distribution, constitute the second tier of constraints. Market access limitations, including price opacity and the absence of certification, restrict the conversion of production growth into proportionate income improvement.

The AHP prioritization exercise identifies drying and processing facility improvement, certified seedling access, port and landing infrastructure, and farmer training and extension as the four highest priority interventions for the near to medium term. Export certification and digital market access tools are important in the longer run but depend on the establishment of the more foundational elements first.

Sustained, consistent, and long term government commitment to each of these priority areas, calibrated to the specific competitive position of each regency, is the central precondition for seaweed development to reach its genuine potential across East Nusa Tenggara. Pilot programs that address one or two constraints in isolation, without a coherent strategy that connects production quality to market access, are unlikely to produce durable improvements. A thorough feasibility assessment of the highest priority infrastructure investments, combined with a structured approach to cooperative governance strengthening, would form an appropriate starting point for the regional planning process.

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