

# UNLOCKING THE POTENTIAL OF SEAWEED AQUACULTURE IN INDONESIA'S BLUE ECONOMY: OPPORTUNITIES AND CHALLENGES

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## ABSTRACT

*Seaweed, or macroalgae, is a vital maritime biological resource with significant potential for aquaculture. Easily found in tropical maritime ecosystems, particularly near the equator in regions like Indonesia, seaweed plays a fundamental role in marine ecosystems. Positioned at the base of the oceanic food chain, it relies solely on sunlight to produce energy. Seaweed contributes positively to environmental health by absorbing carbon dioxide for photosynthesis and releasing oxygen, essential for human respiration. Beyond environmental benefits, seaweed is also an excellent source of protein. Research has shown that even a small amount of seaweed contains substantial protein, making it a promising nutritional resource for maintaining health and physical fitness. Economically, seaweed aquaculture offers a reliable source of income, particularly for coastal communities in Indonesia, where many livelihoods depend on the sea. This industry helps stabilize the region, offering economic security that can reduce negative activities such as piracy and robbery. To maximize the benefits of seaweed aquaculture, effective management is essential. This includes innovative cultivation methods, high-quality seed availability, and strategic regulation of the seaweed value chain to balance supply and demand. With the government's support in managing influencers and stakeholders in the seaweed production chain, this industry has the potential to become a staple of Indonesia's economy, transforming from an emerging industry into a primary economic resource.*

**Keywords:** Blue economy, Renewable Energy, Seaweed aquaculture.

## 1. INTRODUCTION

The Republic of Indonesia is an archipelagic country located between the Pacific Ocean and Indian Ocean around the equator whereas it has 6.32 million km<sup>2</sup> of water space surrounding 17,500 islands. Owing to its blessed condition, so many maritime resources are abundant in this country both, biological or non-biological resources. All those are suitable to be exploited for the welfare of Indonesian peoples maximally. It states clearly in Indonesia's constitution (UUD 1945) article number 33 verse (3); The land, the waters and the natural resources within shall be under the powers of the State and shall be used to the greatest benefit of the people<sup>1</sup>. Then, it became a challenge on how the exploitation of all resources are maintaining the ecosystem as a line of the Blue Economy concept..

Seaweed or Macroalgae is one of the alternative live maritime resources that can live easily around the subsurface of the sea, because it just needs the energy from sunlight to live as the level one of the foundations of the sea's food chain or Photoautotrophs and visible<sup>2</sup>. Moreover, seaweed also contains a rich amount of protein that is needed in human nutrients which has up to 47% of protein on the dry weight especially amino acid<sup>3</sup>. Obviously, it is higher than protein inside the nuts, legumes or wheat that are

produced on the land. Due to those reasons, it will be an opportunity for Indonesian to develop the seaweed as a potential economic activity to be a reliable sector to resilience Indonesia's economy.

Hereinafter, aquaculturing are concatenation activities include selecting a best species of seaweed which is proper to growth in Indonesia sea's water, the nursery to get the seed, making the multi-media for aquaculture to be a reliable livelihood for farmer and the last is how to dry it to be a good dried seaweed which has a competitiveness commodity in international market. Government key roles to support the farmers are in maintaining the seed supply availability and also the price of dried seaweed. It is such a system interconnected to each other in order to reach some benefits of the seaweed aquaculture, they are; Ecosystem sustainability, livelihood reliability, protein for human's nourishment availability and also the national export income increasingly as a better Gross Domestic Product afterward.

## 2. LITERATURE REVIEW

### 2.1 Character of Seaweed

Seaweeds are defined as autotrophic organisms of simple structure with little or no cellular differentiation and complex tissues, so they are *Thallophytes*. After its definition, the first character

about seaweed is its anatomy as a visible plant. In general, seaweed anatomy's consists of three parts, they are;

- Blade or Lamina as seaweed's leaf.
- Stipe as seaweed's stem
- Holdfast and haptera as the basal structure.

Seaweed is a kind of organism which lives as long as it can be reached by sunlight. How easy seaweed can live due to its capability to produce the food by itself or known as autotrophs by processing sunlight and water through photosynthesis. What is more, it can alter carbon dioxide to be oxygen. As an organism, the seaweed needs some requirement to live then grow properly so that role its functions. The main necessity wherever it must be touched by the sunlight. It considers their function as one of primary producers in the environment, specifically marine surroundings. Afterwards, the next condition for them is water as the tangible media for seaweed. The water quality for seaweed to live naturally are temperature, salinity, acidity, phosphate, nitrate, dissolved oxygen, depth, current speed, brightness, total dissolved solids and total suspended solids.

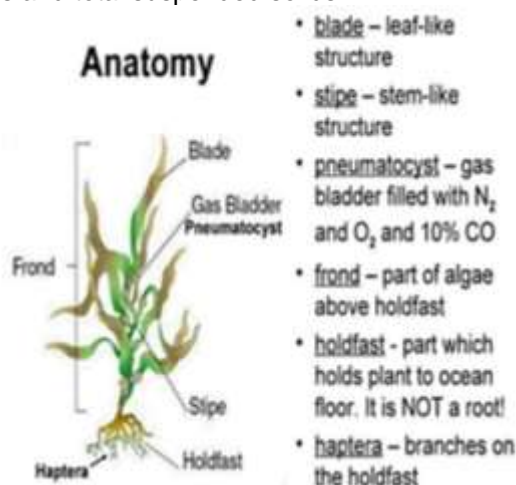


Figure1. Anatomy of Seaweed in general

## 2.2. Economics Parameter

Seaweed aquaculture directly affects Indonesia's macro economy. It is a reliable commodity from Indonesia to the international market chiefly to China, Vietnam, Philippines and Korea accounted for 95% of Indonesian seaweed exports in 2011, with China alone accounting for 68%. Furthermore, Indonesia's export of the carrageenan-yielding *Eucheumatoid* seaweeds by 2015 was 65% of the global total of *Kappaphycus* and 56% of the global total of *Eucheuma*. And it has been sustained until 2020 whereas the Food and Agriculture Organisation (FAO) of the United Nations' 2020 noted that 30% of the seaweed in the world came from Indonesia and it contributed USD 9.3 million to Republic of Indonesia's export in 2018. Seaweed aquaculture has absorbed the worker force in the Republic of Indonesia in a number of 263,586 households in 22 provinces until 2020 based on BPS-Statistics Indonesia. They are all in productive ages (15-65 years old) consisting of male

and female whose education level from not yet graduated primary school until the post graduated.

The price as a factor in chain seaweed production must be highlighted to maintain seaweed production as a reliable commodity. The good price from buyer to the farmer or a good purchase mechanism from industry will stimulate Indonesian to be seaweed farmers and it is obviously hardworking for all who are engaged in. It means the government needs to control the price, not the invisible hand of the private sector. The purpose of leaving poverty from seaweed aquaculture will be achieved after all.

## 2.3 Environment Parameter

Seaweed aquaculture invites sustainability for the environment. Both in small scale, around the certain place where they are living and larger scale that impact the global condition. Thus, the terminology of sustainability consists of a couple meanings. First, it connects to the air cycle on a large scale. Seaweed is a good environmental agent due to its role to generate oxygen which humans need as a fundamental requirement to live.

Secondly, seaweed is not a non-living source that needs to be mined to produce a commodity such as oil, gas, etc. Exploiting seaweed invites the animal trophs above them to survive in the food chain in marine ecosystems. In this term, there is no change of sea morphology during seaweed aquaculture, even more sustaining the balancing of sea environment as per the blue economic maritime concept promulgated by Gunter Pauli for the first time in 2010. Then for themselves, they can cultivate, grow and harvest periodically in about 30-45 days (depending on its species respectively). Apart from sustainability circumstances, seaweed also has a function to mitigate natural disasters, basically the face of increased sea level due to the higher sea temperature, rise, flooding, and storms. Their existences will keep the sea temperature under control through their photosynthesis process

## 2.4 Social Parameter

Referring to the result of a questionnaire conducted from 11th February until 13rd February 2022 with random methods to 300 Indonesians who live in 34 provinces in Indonesia responded that 218 persons or 72.7% interested in becoming a seaweed farmer if the income IDR 8,000,000 per month minimally. Those numbers indicate Indonesians active ages who have interest in seaweed aquaculture, in mathematics it will be  $72.7\% \times 185,453,064 = 134,824,378$ . Salt water intrusions beneath the ground mix to the fresh water then peoples in the surrounding could not use it for their need<sup>48</sup>. If these significant urbanised numbers will make a social gap, especially youth who should care and a main actor in development. Modernisation will be difficult to reach the seaside villages whilst internet and other advanced technology shall assist humans in doing their job and gather all knowledge as a borderless era.

## 2.5 Research and Developments Parameter

The research from upstream to downstream about seaweed is still needed to know deeply about the rotations, the functions, the behaviours then also the extraction from seaweed. Conducting research to know seaweed deeply will make us understand how to live next to them while exploiting them as biological resources. This also refers to the government's role so the government can take the right portion to develop the seaweed, especially the seeds related to the quality and the loop of its life. So, both government and academic institutions who are engaged or interested in conducting the research will have legal references to make it more useful for Indonesians even for the whole of human being.

## 3. RESEARCH METHODS

### 3.1 Research Design

A qualitative approach of methodology will be utilised along the course of research. Framework considered for undertaking this research is as follows:

- a. Identifying major factors which may lead seaweeds aquaculture to be occupied as a promising job for Indonesians.
- b. Expanding the multi functions of seaweed in the environment and requiring human nutrients.
- c. Analysing "Tumpang Sari" means to enhance the harvest of seaweed aquaculture.
- d. Prepare the interview questionnaire.
- e. Comparing the data compiled by primary and secondary resources and carried out to analysis.
- f. Answer the main and sub main questions.
- g. Conclude and recommend.

### 3.2 Data Collection Methods

#### 3.2.1 Literature Review

Gather secondary data from academic journals, government reports, and industry publications on seaweed aquaculture, blue economy principles, and current challenges in Indonesia.

#### 3.2.2 Surveys and Questionnaires

Distribute structured surveys to stakeholders, including seaweed farmers, processors, and government agencies, to gather insights on production challenges, market access, and economic impacts.

#### 3.2.3 Interviews

Conduct semi-structured interviews with key informants, such as policymakers, local officials, researchers, and industry leaders, to understand barriers, opportunities, and policy considerations in expanding seaweed aquaculture.

#### 3.2.4 Field Observations

Visit seaweed farming sites to observe farming techniques, infrastructure, environmental impacts, and community engagement.

## 4. ANALYSIS AND DISCUSSION

### 4.1 Validity of Primary Data

In this research, quantitative analysis is used to know the validity as follow:

- a. Estimated maximum variability is 0.5, because the answer from the questioner just "Yes" or "No".
- b. Expected Margin of Error. From this random survey, it has 5.7%~6%. It means, just 6% of responders did the error or mistake when they answered it.
- c. Confidence Level. The confidence level 98% indicating the result will be the same until 98 times or in another word, it is named valid as a data and it may be used in an analysis to get the strong argument.

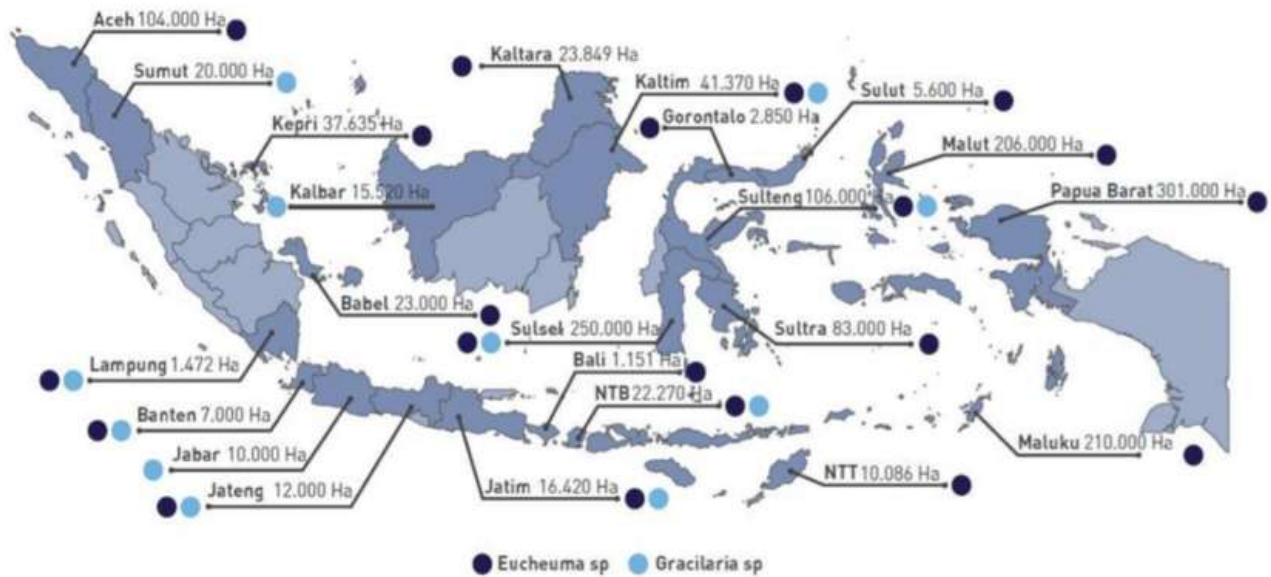
### 4.2 Potential Seaweed Aquaculture

This potential reality can be analysed both quantitatively and qualitatively as below:

- a. Appointing graphics 2.2., 97% Indonesians knew about seaweed. So, it indicates  $97\% \times 185,453,064$  (Indonesian population in February 2022) = 179,889,472 Indonesians knew seaweed quantitatively, maybe as a kind of plant in the sea or as a promising living resource, etc. today. It may be said that most Indonesians know what seaweed is qualitatively.
- b. Appointing graphics 2.3., 72.7% of Indonesians are willing to be a seaweed farmer if the income Rp. 8,000,000 (eight million Rupiahs) per month minimally or above the living cost. So, it indicates  $72.7\% \times 185,453,064$  (Indonesian population in February 2022) = 134,824,378 Indonesians think a seaweed farmer income as a promising job quantitatively. It could be they know it previously or they don't know the average income to be a seaweed farmer, they just want to know if it could be saved or not from the monthly income. In this way, they believe they can get wealthy qualitatively.
- c. Appointing graphics 2.4., 45% Indonesians knew the Republic of Indonesia as the biggest seaweed exporter in the world. So, it indicates  $45\% \times 185,453,064$  (Indonesian population in February 2022) = 83,453,879 Indonesians knew that Indonesia's seaweed has a market over the world quantitatively. It is less than half of Indonesia's population. It must be a lack of information. Then, it may be said that less of Indonesians know that seaweed is a prospective business from Indonesia due to its international market qualitatively.

### 4.3 Factors Leading Seaweed as a Promising Aquaculture for Indonesians

The Ministry of Marine Affairs and Fisheries (KKP) has mapped the area in Indonesia with a total of 1,510,223 hectares in 2021 where proper for seaweed aquaculture over the 23 provinces from the total 34 provinces in Indonesia as picture below:

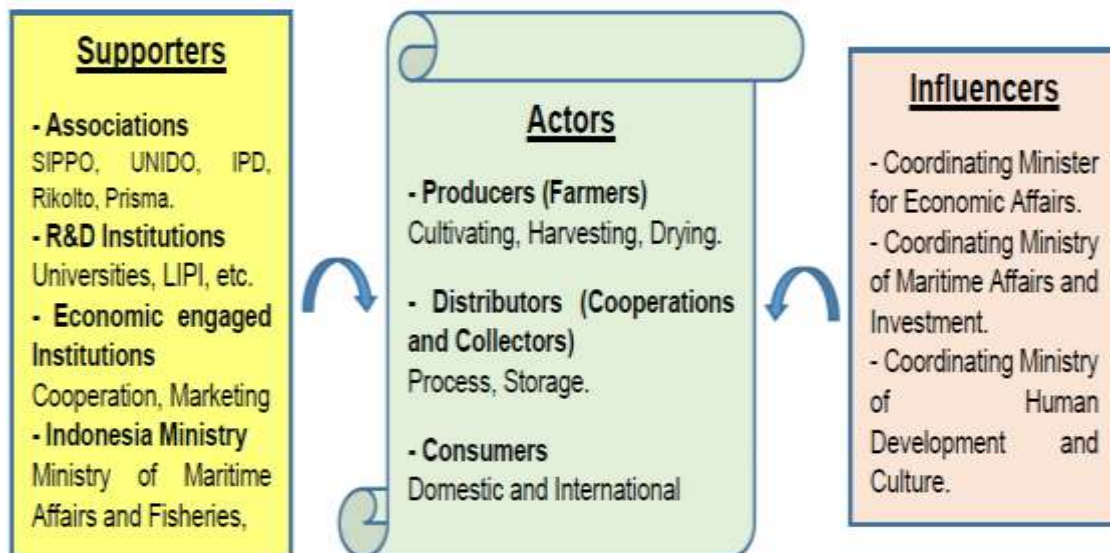


**Figure 2.** Map of potential area for seaweed in the Republic of Indonesia

The next factor is the species. Seed availability plays an important role in seaweed's chain of value. This significantly affects the quantity and quality of the seaweed production. Genetic engineering is needed through continuous research, both from government institutions and academic institutions in Indonesia.

The developing role of Marine Cultivation Fisheries Centre (BBPBL) as the executor of

government inguding and directing the farmer under control of KKP will maintain the availability of seed to the farmer. The value chain will have the standard for the quality and quantity to maintain the supply and demand of the seaweed, then, the value chain shows as under:



**Figure 3.** Organogram the Seaweed Value Chain

The next factor is the method in seaweed aquaculture. Most of Indonesians seaweed aquaculture do the traditional method as a legacy from their parents or their surrounding. Although cultivating

seaweed has low cost, leaving the traditional methods will make a great impact both to the farmer as well to the state's income. The comparison show in table under:

**Table 1.** Comparison Traditional methods to Modern Methods

NO.	FACTOR	METHODS	
		MODERN	TRADITIONAL
1.	Season	Not Impact	Depply impact
2.	Seed availability	Sustainable	In dry season
3.	Area	Prefer from 6-20 meters	Shallow water
4.	Capability area	Heterogeneous Cultivating	Homogenous Cultivating
5.	Capital	Bigger	Lower

Table 1 compares modern and traditional seaweed cultivation methods across several factors, revealing distinct differences in their approaches and outcomes. Modern methods are less affected by seasonal changes, ensuring more stable production, while traditional methods are significantly impacted by seasonality. In terms of seed availability, modern techniques offer a sustainable supply, whereas traditional methods rely on availability mainly during the dry season. Modern cultivation is suitable for deeper areas (6-20 meters) and supports heterogeneous cultivation, allowing for diverse growth. In contrast, traditional methods favor shallow waters and involve more homogenous cultivation. Capital requirements differ notably; modern cultivation demands higher investment, while traditional

approaches require less capital, making it potentially more accessible but less scalable. These differences highlight how modern techniques may offer more stable and scalable options, albeit with higher initial investment, whereas traditional methods are more cost-effective but dependent on environmental factors.

#### 4.4 SWOT Analysis

Some tangible factors in all parameters as strengths or weaknesses must be managed to way forward all opportunities without awareness of all threads. Hence, Indonesia will not lose its golden chance to put its interest while walking toward the welfare for all Indonesians. The categorised is show in table below:

**Table 2.** Tabulation of Seaweed Aquaculture Parameter in SWOT analysis for internal factor

INTERNAL	ASPECTS	
	STRENGTH	WEAKNESS
INTERNAL	- Increase the GDP.	Price Control
	- Absorb the workforce.	
	- Even the distribution of people.	Less of Information
	- Even the advanced technology.	
	Sustainability ecosystem.	- Seaweed's Disease
	- Maintain air quality.	- Necessitating to update the sea lane chart
	- Mitigating the sea natural disaster	
	- Sufficient engaged Institution.	May be insufficient IT such as Wi Fi signal
	- Government policy.	
	- Prevent the crime	Less of reporting
	- Prevent radicalism and terrorism	
	- Far away from land properties conflict.	
	- Male and Female	

This table outlines the internal strengths and weaknesses associated with seaweed cultivation in Indonesia. Strengths include economic benefits such as an increase in GDP and job creation, as well as societal advantages like population distribution, technological advancements, and ecosystem sustainability through improved air quality and disaster mitigation. Government policies and institutional

support further strengthen this industry by helping regulate and secure coastal regions, reducing crime and radicalism risks, and avoiding land conflicts. However, weaknesses highlight challenges such as price control difficulties, limited information access, and a need for updated sea lane charts. Additionally, issues like seaweed diseases, limited IT infrastructure (e.g., Wi-Fi connectivity), and insufficient reporting

pose potential barriers. These strengths and weaknesses reveal the need for balanced

management to optimize benefits while addressing logistical and technological challenges.

**Table 3.** Tabulation of Seaweed Aquaculture Parameter in SWOT analysis for external factor

ASPECTS		
EXTERNAL	OPPORTUNITIES	THREAT
	- National policy. - Possibilities to develop another economic business	Corruption.
	Youth to participate in developing.	Adaptation to a new circumstance/social conflict.
	Seawater space utilisation	- Pollutants. - Big natural disaster.
	- Seed research. - Price research. - Extract research	Accident by human error.
	Participating in sea security	Robbery the harvest

This table outlines the external opportunities and threats affecting the seaweed industry in Indonesia. Opportunities include supportive national policies and the potential to diversify economic ventures linked to seaweed. Additionally, there is an opportunity to engage youth in the sector, fostering innovation and future growth. The vast utilization of seawater space opens more avenues for expansion, while ongoing research in seed, price, and extract development aims to improve productivity and profitability. Participation in sea security efforts further supports stable and safe operations. However, the industry faces threats such as corruption, social conflict, pollution, and the risk of natural disasters, which could disrupt activities and harm productivity. Human error poses a risk of accidents, and the possibility of harvest theft by robbers highlights the need for strengthened security.

These opportunities and threats underline the sector's potential for growth alongside the challenges that must be managed for sustainable success.

Referring to the table, it elaborates conscientiously all benefits that may get through seaweed aquaculture notably from strengths and opportunities. Then, all benefits are going to come true if in the way forward pondering all weakness and thread. In this regard, all probable weakness will be beaten out by the strangeness as a proven thing which has brought the Republic of Indonesia as a biggest exporter of seaweed. Then all the threads will be coped with the opportunities as of their quantity's comparison in the table in a glance. Then, all acquired will positively increase the national resilience of Indonesia amongst the dynamic conditions of the world.



**Figure 4.** Schematic benefits acquired using SWOT Analysis for Indonesia

Defining all challenges will be a good step to know how to manage the power that may swiftly seaweed aquaculture as potential to be reliable. By SWOT analysis, all influenced aspects have been categorised to make it clear on how strategy will be taken to pass over the challenges smoothly. It includes inner challenges that should be built to survive the nowadays conditions and the rest is outer challenges that expand the seaweed aquaculture to be a reliable business from the upstream to the downstream in Indonesia that may impact the resilience in any sectors.

For seaweed aquaculture, it is important to consider all Indonesians' strengths as a value authorised asset that should be organised hierarchically from national to the country level to counter all weaknesses. Utilisation of all institutions engaged, both under the government or privately supported by fluency of information will be an excellent formula to kick off the collaborating system in the seaweed value chain. In this regard, it will build a competitive mentality for Indonesians to get or extend the market for seaweed as an essential challenge. By natural selection along with the time, it will bring Indonesia to survive as the biggest exporter of raw seaweed material in the world.

## 5. CONCLUSIONS AND SUGGESTIONS

### 5.1 Conclusions

Based on the result and discussions above there are some conclusions that can be taken, as follows:

- a. Seaweed is more than just a natural beauty beneath the sea; it is a valuable resource from nature that, with proper aquaculture, can provide significant economic and environmental benefits for coastal communities in Indonesia.
- b. Recognizing seaweed's potential, the Indonesian government created a strategic roadmap in 2019 to promote seaweed as a key sector, aiming for economic, social, and environmental stability and growth through coordinated efforts.
- c. With effective management of resources and overcoming challenges, Indonesia has the potential to strengthen its maritime influence, aligning with the President's vision to establish Indonesia as a central maritime power, ensuring benefits for future generations.

### 5.2 Suggestions

Based on the conclusions above, there are some suggestions that can be taken, as follows:

- a. Prioritize the cultivation of red algae (Rhodophyta), which has high market demand and valuable extracts across industries. Until new, more resilient seaweed species are developed, red algae should be the focus for reliable aquaculture expansion.
- b. Update Indonesia's seaweed policy to extend beyond 2021, supporting every stage of the seaweed value chain from production to processing. This will

help stabilize seaweed prices and availability and aid economic recovery post-COVID-19.

- c. Ease investment regulations in Indonesia's maritime sector to attract global investors in seaweed aquaculture and related industries. This will support mutual economic benefits, reinforcing Indonesia's identity and potential as a thriving maritime nation.

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