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Original Article

A Model for Community-Based Seaweed Cultivation in South-west Maluku, Indonesia: Strengthening Coastal Livelihoods

Nurjanah Nurjanah [a,*], Alinda Cahyani [a] and Sutaman Sutaman [a]

[a] Department of Aquaculture, Faculty of Fisheries and Marine Science, Pancasakti University Tegal, 52121 Kota Tegal, Jawa Tengah, Indonesia; alindacahyani@gmail.com (A.C.); sutaman@upstegal.ac.id (S.T.M.)

* Correspondence: nurjanah@upstegal.ac.id (N.N.)

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Abstract: Institutional development plays a vital role in advancing the success and sustainability of community-based seaweed farming, particularly in Southeast Maluku, Indonesia. This study seeks to design a comprehensive institutional model tailored to the unique needs of seaweed farming communities in the region. The model emphasizes four key components: the division of tasks among stakeholders, effective and inclusive decision-making processes, transparent and accountable financial management systems, and robust monitoring and evaluation mechanisms. These elements are designed to strengthen institutional capacity and foster greater collaboration among farmers. The central hypothesis of this study is that by improving institutional structures, farmers will experience enhanced cooperation, increased bargaining power within the seaweed supply chain, and improved sustainability of their cultivation practices. A well-structured institution can support fairer market access, equitable profit distribution, and collective resilience to economic and environmental challenges. In turn, these improvements are expected to lead to more stable and long-term farming practices. The proposed institutional model not only aims to increase the economic viability of seaweed farming but also to promote social cohesion and environmental stewardship within coastal communities. The study aspires to enhance the overall welfare of seaweed farmers by ensuring that institutional arrangements are both participatory and adaptive to local contexts. Ultimately, this research contributes to the broader discourse on institutional design in small-scale agriculture and aquaculture. It offers a replicable model that can be adapted for similar community-based farming initiatives in other coastal and rural regions, both within Indonesia and beyond.

Keywords: Seaweed cultivation; Community-based model; Sustainability; Public welfare.

1. Introduction

Modeling for seaweed cultivation is a complex endeavor involving many interrelated variables. Some common problems often encountered in this modeling process include the modeling of seaweed cultivation, which faces the challenges of the complexity of marine ecosystems, limited historical data, and spatial data that affect the accuracy of predictions of growth and productivity (Noor, 2013; Pascoe, 2019). The complexity of marine ecosystems plays an essential role in determining the conditions of a very dynamic marine environment (Buchori et al., 2018; Narwal, Kaur, Yadav, & Bast, 2024). The difficulty of this detection requires modeling assistance in addition to building factors such as temperature, salinity, currents, and nutrient availability that are difficult to predict accurately (Farias, Rave, Siddique, & Müller, 2023). The biological interactions of seaweed with various other marine organisms, such as phytoplankton, zooplankton, and bacteria, can affect their growth and productivity. The biogeochemical process then assists them with nutrient and energy cycles in the sea, which is complex and challenging to model completely. Therefore, a good model is needed (Hadiyanto, Arief Rahman Halim, Muhammad, Soeprobowati, & Sularto, 2021; Sanjaya, Merit, & Astarini, 2022).

Accurate historical and spatial data is a significant obstacle in developing comprehensive seaweed farming models. As a result, the resulting models often need to be more precise and straightforward to rely on in predicting production dynamics and optimizing farming management (Banikoi, Schlüter, & Manlosa, 2023; Chlomoudis, Kostagiolas, Pallis, & Platias, 2024). Accurate and complete historical and spatial data are required to build a comprehensive seaweed cultivation model. Unfortunately, the limited data is a significant obstacle in developing a reliable model. Developing a precise seaweed cultivation model depends on historical and spatial data availability. However, the lack of such data is often a significant obstacle to achieving these goals (Mardiyani, 2015; Rami, Faiq, Aziz, & Muhamad, 2021; Zhu, Wang, & Sun, 2019). Model development involves selecting the right software from various options but requires adequate programming, statistics, and marine ecology user skills to build and run the model. The need for accurate historical and spatial data is a significant barrier to developing comprehensive seaweed farming models (Shang, Zhang, Zhang, Zhang, & Zhang, 2025; Yakubu, Falconer, & Telfer, 2025). Model development involves selecting the right software from various available options but requires adequate programming, statistics, and marine ecology user skills to build and run the model. As a result, the resulting models often need to be more precise and straightforward to rely on to predict production dynamics and optimize aquaculture management (Claisse et al., 2014; Wagey, Boneka, & Mantiri, 2020).

2. Materials and Methods

This study was conducted by creating a mathematical or computer model to describe a natural system or process. In the context of seaweed cultivation, the model is used to predict growth, yields, and factors that influence cultivation(Irawan et al., 2023; Lestari, Wibowo, & Rahayu, 2021; Sarwidi, Aji, & Satyarno, 2019). It is assisted by a cultivation approach that involves active community participation in all stages of cultivation, from planning to marketing. Area-based shrimp farming (BUBK) was introduced in February 2023, an environmentally friendly BUBK operating on the coast of Kebumen, Central Java. In this case study, 149 shrimp farmers manage 60 hectares of land that will be expanded to 100 hectares. Fish farming in Cikoneng Village. Then in another place, in Cikoneng Village, Ciamis, implementing sustainable practices to protect the environment and ensure the future of the fisheries industry. Community-based seaweed cultivation modeling research aims to: (1) Identify important variables that influence seaweed growth and production. (2) Develop models to predict harvest results based on environmental conditions and cultivation inputs. (3) Compare various cultivation strategies to determine the most effective and efficient. (4) Involve the community in the data collection and model creation process to increase ownership and sustainability of cultivation.

3. Results and Discussion

As a supplier of seeds for modeling, you must be able to produce seeds in the right amount of time. Based on the development plan, the seeds used in modeling measure 50x50 meters, totaling 15 units. The total area is 37,500 hectares. Location is determined in the waters of Ohoi Letfoan, Hoat Sorbay District. The condition of the seas in Letfoan is correct at the mouth of Hoat Sorbay Bay, where, based on experience and the results of water quality measurements, this location is very suitable for cultivation activities. Seaweed production and productivity in this area are the highest compared to all seaweed cultivation areas in Southeast Maluku (Renjaan & Raka Susanty, 2020; Wibawa et al., 2021). Another characteristic of this area is that seaweed cultivation activities can occur throughout the year. The bay area is relatively narrow and winding, so the design is adjusted to the water conditions in Ohoi Letfoan. The design of the Starter Garden and Seaweed Seed Garden is presented in Figure 1.

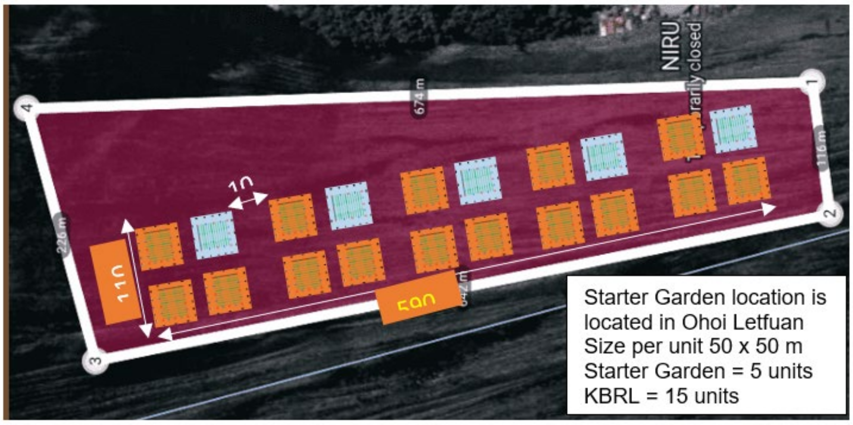
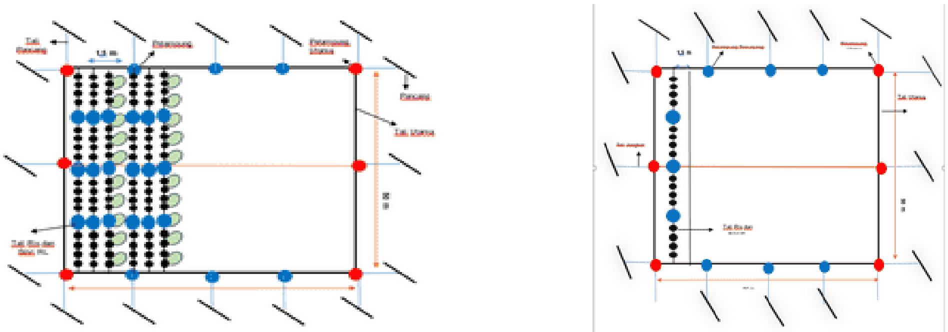


Figure 1. Starter Garden Layout for Modeling area

The seaweed seed garden is supported by five starter gardens, each of which is the same size as the main unit. The layout of both the seed and starter gardens is shown in Figure 2.



(**a**) (**b**)

Figure 2. (a) Design of the Starter Garden Pilot Unit; (b) Design of the Nursery Garden Pilot Unit

The specifications of the materials used for the construction of starter gardens and seaweed seed gardens can be presented in Tables 1 and 2 as follows:

Table 1. Specifications of materials and volume of goods used for the construction of the Starter Garden in Southeast Maluku

No.	Component	Volume	Information
1	Seaweed Seeds (Cotonii)	198 Kg	Originating from UPT DJPB or Pokdakan Fostered by UPT DJPB
2	Main Rope	224 Meter	PE material diameter 12 mm,
3	Anchor Rope	450 Meter	PE material diameter 14 mm
4	Support Rope	56 Meter	PE material diameter 12 mm,
5	Ris Rope	1,560 Meters	Southeast Maluku PE material diameter 5 mm,
6	Rope Tie the ris rope to the auxiliary rope	9 Meter	Southeast Maluku PE material diameter 5 mm,
7	Lifebuoy Rope	204 Meter	PE material diameter 3 mm
8	Seedling Binding Rope	1,188 Meters	PE material diameter 2 mm,
9	Coconut shell buoy rope	144 Meter	PE material diameter 3 mm,
10	Basket Tie Rope to the ris rope	50 Meter	PE material diameter 5 mm,

11	Planet Rope	110 meters	PE material diameter 2 mm,
12	Main Buoy	6 units	ball shape, diameter 40 cm, HDPE material, uniform color
13	Support Buoy	96 units	ball shape, diameter 20 cm, HDPE material, uniform color
14	Coconut Shell Float	480 units	comes from old coconuts with hard shells; the outside is clean from fibers; the circumference of the middle circle is at least 35 cm, using strong and waterproof adhesive glue; the hook is made of 7 mm PE rope with a length of 10 cm. Filled with Styrofoam, the outside is covered with Mat/fiber and Resin. Doesn't leak
15	Weight / Anchor	36 units	Concrete ballast measuring 50 Kg, with dimensions of 0.25 x 0.25 x 0.34 m Concrete (1pc: 2ps: 3Kr), 14 mm PE rope for lifting with an outer length of 10 cm and an inner length of 40 cm
16	Basket	100 pairs	Size diameter 30 cm, uniform color

Source: Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia (2024)

Table 1 provides a detailed list of materials, and their respective volumes required for the construction of a starter garden for seaweed farming in Southeast Maluku. The materials outlined ensure the establishment of a functional and sustainable seaweed cultivation system, supporting various essential tasks such as seedling cultivation, flotation, stability, and anchorage. The foundation of the farming system begins with 198 kg of seaweed seeds (Cotonii), which are sourced from UPT DJPB or local farmer groups (Pokdakan) under the guidance of UPT DJPB. To support the structure, 224 meters of main rope, made from polyethylene (PE) material with a 12mm diameter, are used. Similarly, 450 meters of anchor rope, with a 14mm diameter, and 56 meters of support rope, also made of PE material, help stabilize the farming units in the water. The system requires 1,560 meters of ris rope (5mm diameter), ensuring proper attachment of seaweed seedlings. Additionally, 9 meters of rope are designated for tying the ris rope to the auxiliary ropes, further supporting the cultivation process. For flotation, 204 meters of lifebuoy rope (3mm diameter) are included to ensure that the system remains buoyant and stable.

Seedlings are bound securely using 1,188 meters of binding rope (2mm diameter), while 144 meters of coconut shell buoy rope (3mm diameter) are used to secure the flotation devices. To attach baskets to the ris ropes, 50 meters of rope (5mm diameter) are provided, facilitating the collection and management of the seaweed. Other components include 110 meters of planet rope (2mm diameter) for additional structural support, 6 main buoys (40 cm diameter, HDPE material), and 96 support buoys (20 cm diameter, HDPE material), both providing necessary buoyancy. The coconut shell floats, totaling 480 units, are crafted from old coconuts with clean, hard shells, filled with Styrofoam, and coated with mat/fiber and resin to ensure durability and leak-proof functionality. Finally, the system is anchored using 36 concrete ballast weights, each weighing 50 kg and measuring 0.25 x 0.25 x 0.34 meters. These ballasts are reinforced with 14mm PE ropes for secure lifting and positioning. The setup is completed with 100 pairs of baskets, each with a 30 cm diameter, providing a uniform structure for holding the seaweed during its cultivation. These materials are selected for their strength, durability, and suitability for marine environments, ensuring the success and sustainability of the seaweed farming system in Southeast Maluku. The specifications of the materials used for the construction of the Southeast Maluku Regency seaweed seed garden are presented in Table 2:

Table 2. Specifications of materials and volumes used for the Seaweed Seed Garden

No.	Component	Volume	Information
1	Seaweed Seeds	297 Kg	Kappa Kuljar seeds originating from UPT DJPB or Pokdakan fostered by UPT DJPB and attaching a SKA
2	Main Rope	224 Meter	PE material 12 mm diameter, 6-month guarantee, equipped with Lab Tests
3	Anchor Rope	450 Meter	PE material, diameter 14 mm, 6-month guarantee, equipped with lab tests

4	Support Rope	56 Meter	PE material 12 mm diameter, 6-month guarantee, equipped with Lab Tests
5	Ris Rope	1,560 Meters	PE material diameter 5 mm, 6-month guarantee, equipped with Lab Tests
6	Rope Tie the ris rope to the auxiliary rope	9 Meter	PE material diameter 5 mm, 6-month guarantee, equipped with Lab Tests
7	Lifebuoy Rope	204 Meter	PE material 3 mm diameter, 6-month guarantee, equipped with Lab Tests
8	Coconut shell buoy rope	144 Meter	PE material 3 mm diameter, 6-month guarantee, equipped with Lab Tests
9	Seedling Binding Rope	1,782 Meters	PE material diameter 2 mm, 6-month guarantee, equipped with Lab Tests
10	Main Buoy	6 units	ball shape, diameter 40 cm, HDPE material, uniform color
11	Support Buoy	96 units	ball shape, diameter 20 cm, HDPE material, uniform color
12	Coconut Shell Float	480 units	comes from old coconuts with hard shells; the outside is clean from fibers; the circumference of the middle circle is at least 35 cm, using strong and waterproof adhesive glue; the hook is made of 7 mm PE rope with a length of 10 cm. It is filled with Styrofoam, and the outside is covered with Mat/fiber and Resin. It Doesn't leak
13	Weight / Anchor	36 units	Concrete weight measuring 50 Kg, with dimensions of 0.25 x 0.25 x 0.34 concrete (1pc : 2ps: 3Kr), 14 mm PE rope for lifting with an outer length of 10 cm and an inner length of 40 cm

Source: Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia (2024)

Table 2 indicates the materials, and their volumes required for the construction and establishment of the Seaweed Seed Garden in Southeast Maluku. These components are crucial for ensuring the successful cultivation, stability, and long-term sustainability of the seaweed farming system. The seaweed farming operation begins with 297 kg of Kappa Kuljar seaweed seeds, sourced from UPT DJPB or local Pokdakan groups under the guidance of UPT DJPB. These seeds are accompanied by a Seaweed Quality Assurance (SKA) certificate, ensuring their quality and suitability for cultivation. To support the structure of the seaweed farming system, 224 meters of main rope made from polyethylene (PE) material with a 12mm diameter are used. Similarly, 450 meters of anchor rope with a 14mm diameter are utilized, as well as 56 meters of support rope (12mm diameter), all made of PE material and tested for quality through lab certifications, with a 6-month guarantee. The ris ropes, used to attach seedlings to the farming system, total 1,560 meters and are made of PE material with a 5mm diameter. An additional 9 meters of PE rope (5mm diameter) are used to tie the ris ropes to auxiliary ropes, enhancing the overall structure. For flotation and stability, 204 meters of lifebuoy rope (3mm diameter) and 144 meters of coconut shell buoy rope (3mm diameter) are included, both of which are made from PE material and come with lab certifications and a 6-month guarantee.

To secure the seedlings to the farming structure, 1,782 meters of seedling binding rope (2mm diameter) are provided, ensuring proper attachment and growth. The farming system also includes 6 main buoys, each with a 40 cm diameter, made from high-density polyethylene (HDPE) material, which provide essential buoyancy. In addition, 96 support buoys, each 20 cm in diameter, are also made from HDPE material and help maintain the stability of the seaweed farming system. Coconut shell floats, totaling 480 units, are used to further support the farming system. These floats are sourced from old coconuts with hard shells, which are cleaned and treated to ensure they are free of fibers. The floats are filled with Styrofoam and covered with mat/fiber and resin for added durability, ensuring they are leak-proof. To secure the entire system to the seabed, 36 concrete ballast weights, each weighing 50 kg and measuring 0.25 x 0.25 x 0.34 meters, are used. These weights are connected to the system with 14mm PE ropes, ensuring secure anchoring. These materials are carefully selected for their strength, durability, and suitability for marine environments, ensuring that the seaweed farming system is both effective and sustainable.

3.1. Seaweed Seed Production Plan

The primary assumption in calculating seaweed seed production is that seeding activities can occur throughout the year(Nia Sarinastiti & Sidiq Wicaksono, 2020; Weinberger et al., 2021). Farmers in Ohio Letfoan have confirmed this assumption, stating that the waters in the location can be used for seaweed cultivation without being affected by the season. If the seeding period is 35 days per cycle, then in one year, the seeds can be harvested 10 times (cycle). The calculation of seaweed seed production is presented in the Table 3:

Table 3. Production Calculation for Modeling

No	Parameter Components	Volume	Unit
1	Length of rope per span	50	meters
2	Length of 1 research unit	50	meters
3	Distance between rope spans	1.5	meters
4	Planting distance between binding points	30	Cm
5	Number of tie points per rope	165	point
6	Number of span ropes	30	fruit
7	Number of points per unit	4,940	fruit
8	Number of seeds per point	50	kg
9	Number of seeds per unit	247	kg
10	Length of nursery time	40	day
11	Length of cultivation period	12	month
12	Maintenance cycle/year	8	cycle
13	RL growth rate per cycle	400	percent
14	RL Seed Production per unit/cycle	988	kg
15	Number of research units	15	unit
16	RL Seed Production in its entirety/cycle	15	ton
17	Total RL Seed Production/year	119	tons/year

Table 3 presents a comprehensive calculation of the production potential for the modeled seaweed cultivation system. The model is designed based on specific parameters related to planting structure, spacing, growth cycles, and yield outputs. Each span of seaweed rope used in cultivation is 50 meters long, matching the length of one research unit. The spacing between each rope span is maintained at 1.5 meters, providing adequate room for seaweed growth and ease of maintenance. Along each rope, seedlings are tied at 30 cm intervals, resulting in 165 planting (tie) points per rope. With 30 rope spans used per unit, each unit contains a total of 4,940 tie points for seedling attachment. Each planting point receives approximately 50 grams of seaweed seeds, amounting to a total seed requirement of 247 kg per unit. The nursery period for seedling growth is set at 40 days, followed by a 12-month cultivation period divided into 8 maintenance cycles per year. During each cycle, the seaweed undergoes rapid linear (RL) growth, with an average growth rate of 400% per cycle. Based on these parameters, each unit produces approximately 988 kg of RL seeds per cycle. With 15 cultivation units established within the modeled area, the total RL seed production per cycle reaches 15 tons. When extrapolated across all 8 cycles annually, the modeled system yields an estimated 119 tons of RL seed production per year. This production model highlights the scalability and high productivity potential of community-based seaweed farming, offering a replicable framework for sustainable aquaculture development in Southeast Maluku and similar coastal regions.

Figure 3. Layout of Seaweed Cultivation Modeling Area

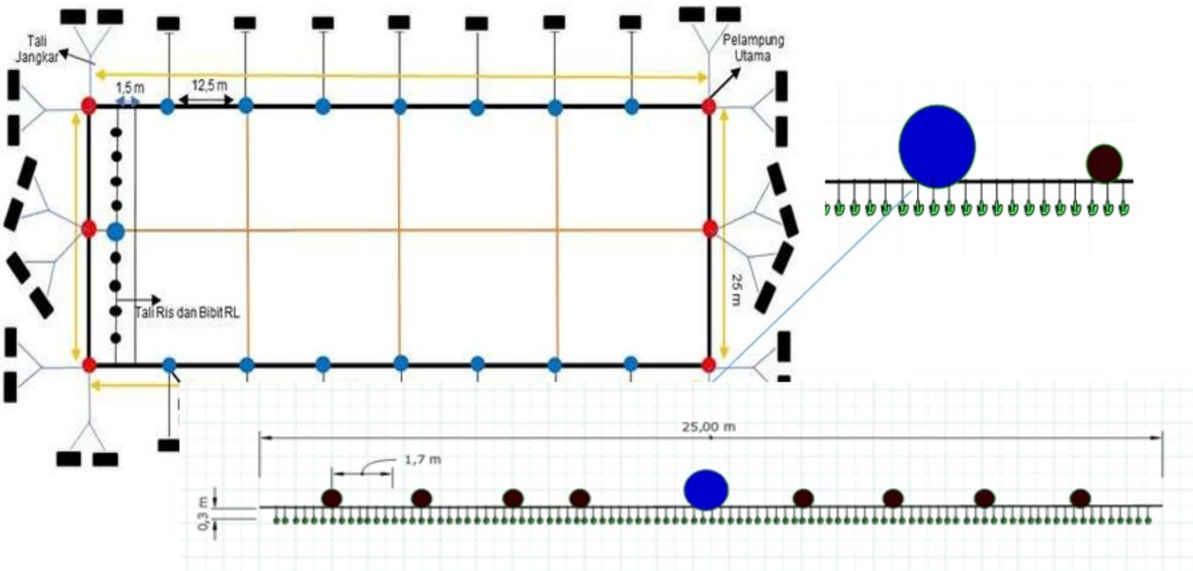


Figure 4. Seaweed Cultivation Design in Modeling Area

The specifications of the materials used for the construction of seaweed cultivation in the seaweed modeling area in Southeast Maluku Regency can be presented in Table 4 as follows:

Table 4. Specifications of materials and volume of seaweed cultivation in the seaweed modeling area in Southeast Maluku Regency

No	Component	Volume	Information
1	Seaweed Seeds	303.8 Kg	Kappa Kuljar seeds originating from UPT DJPB or Pokdakan fostered by UPT DJPB and attaching a SKA
2	Main Rope	274 Meter	PE material 12mm diameter, 6-month guarantee, equipped with lab tests
3	Anchor Rope	594 Meter	PE material 14mm diameter, 6-month guarantee, equipped with Lab Tests
4	Support Rope	199 Meter	PE material 12mm diameter, 6-month guarantee, equipped with lab tests
5	Ris Rope	1,674 Meters	PE material diameter 5 mm, 6-month guarantee, equipped with Lab Tests

6	Rope Tie the ris rope to the auxiliary rope	18.6 Meters	PE material diameter 5 mm, 6-month guarantee, equipped with Lab Tests
7	Lifebuoy Rope	164 Meter	PE material 3mm diameter, 6-month guarantee, equipped with Lab Tests
8	Coconut shell buoy rope	148.8 Meters	PE material 3mm diameter, 6-month guarantee, equipped with Lab Tests
9	Seedling Binding Rope	1,822.8 Meters	PE material 2mm diameter, 6-month guarantee, equipped with Lab Tests
10	Main Buoy	6 units	ball shape, diameter 40 cm, HDPE material, uniform color
11	Support Buoy	76 units	ball shape, diameter 20 cm, HDPE material, uniform color
12	Coconut Shell Float	496 units	comes from old coconuts with hard shells; the outside is clean from fibers; the circumference of the middle circle is at least 35 cm, using strong and waterproof adhesive glue; the hook is made of 7 mm PE rope with a length of 10 cm. It is filled with Styrofoam, and the outside is covered with Mat/fiber and Resin. Doesn't leak
13	Weight / Anchor	38 units	Concrete ballast measuring 50 Kg, with dimensions of 0.25 x 0.25 x 0.34 m Concrete (1pc: 2ps: 3Kr), 14 mm PE rope for lifting with an outer length of 10 cm and an inner length of 40 cm

Source: Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia (2024)

Table 4 outlines the specifications and volumes of materials required for the seaweed cultivation operations in Southeast Maluku Regency, Indonesia. The seaweed farming system begins with 303.8 Kg of Kappa Kuljar seeds, sourced from UPT DJPB or local Pokdakan groups, accompanied by a Seaweed Quality Assurance (SKA) certification to ensure seed quality. The farming structure utilizes several types of ropes, including 274 meters of main rope (12mm diameter), 594 meters of anchor rope (14mm diameter), and 199 meters of support rope (12mm diameter), all made from durable polyethylene (PE) material with a 6-month warranty and lab certification. Additionally, 1,674 meters of ris rope (5mm diameter) are used to attach seaweed seedlings to the farming system, while 18.6 meters of rope are dedicated to tying ris ropes to auxiliary ropes. For buoyancy, 164 meters of lifebuoy rope (3mm diameter) and 148.8 meters of coconut shell buoy rope (3mm diameter) are used to secure flotation devices, ensuring the stability of the farming units. To bind seedlings securely to the system, 1,822.8 meters of seedling binding rope (2mm diameter) are required. The system also includes 6 main buoys (40 cm diameter, HDPE material) and 76 support buoys (20 cm diameter, HDPE material) to maintain surface stability. Coconut shell floats, 496 units in total, are crafted from old coconuts, filled with Styrofoam, and covered with resin for leak-proof flotation. Finally, 38 concrete ballast weights, each weighing 50 kg and measuring 0.25 x 0.25 x 0.34 meters, are used as anchors to secure the farming system to the seabed. These ballasts are connected by 14mm PE ropes for reliable anchoring. The materials listed are all selected for their durability, strength, and suitability for marine environments, ensuring the long-term success and sustainability of the seaweed farming initiative.

4. Conclusions

This study highlights the vital importance of strong institutions in promoting the sustainable development of community-based seaweed farming in Southeast Maluku. The research demonstrates that well-established institutions play a central role in fostering collaboration among farmers, enhancing their bargaining power within the supply chain, and ensuring responsible management of marine resources. These factors collectively contribute to the long-term economic and social well-being of coastal communities. The proposed institutional model offers a valuable framework that can be adopted not only in Southeast Maluku but also by other coastal communities, both locally and globally. It emphasizes the essential link between institutional development and the success of sustainable aquaculture initiatives, showcasing how effective governance structures can empower communities to thrive while ensuring environmental sustainability. The study's findings underline the need for long-term strategies that prioritize both community welfare and ecological balance. The model serves as a call to action for policymakers, stakeholders, and local leaders to invest in strengthening institutional frameworks that support sustainable practices in aquaculture. By adopting such models, communities can better navigate challenges and build resilience against environmental and economic pressures. The broader implications of this research suggest that well-designed institutions are key to unlocking the full potential of coastal aquaculture, fostering not only economic growth but also social equity and environmental stewardship. Ultimately, this study sets the foundation for future efforts to integrate sustainable aquaculture into the broader coastal development agenda, ensuring that coastal communities continue to thrive for generations to come.

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