International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 4
ISSN: 2088-5334

Coastal Communities' Empowerment through Seaweed (*Eucheuma cottoni*): Potency, Suitability, and Local Participation

Zakirah Raihani Ya'la [a,*], Dwi Sulistiawati [b], Sisfahyuni Aziz [c], Ma'ruf Kasim [d], La Ode M. Aslan [e], Nasmia [a], Akbar Marzuki Yahya [a]

[a] *Department of Aquaculture, Faculty of Animal Husbandry and Fisheries, Tadulako University, Palu, 94148, Indonesia*
[b] *Faculty of Animal Husbandry and Fisheries, Tadulako University, Palu, 94118, Indonesia*
[c] *Department of Agribusiness, Faculty of Agriculture, Tadulako University, Palu, 94118, Indonesia*
[d] *Department of Water Resources Management, Faculty of Fisheries and Marine Science, Universitas Halu Oleo, Kendari, 93232, Indonesia*
[e] *Department of Aquaculture, Faculty of Fisheries and Marine Science, Universitas Halu Oleo, Kendari, 93232, Indonesia*
*Corresponding author: *zakirahraihaniyala@gmail.com*

***Abstract*— Indonesia is the largest producer of seaweed contributed by coastal communities, but they still live in precarious conditions. To bolster the seaweed cultivation and alleviate poverty, a coastal community's empowerment was studied in Salabangka archipelagoes through the evaluation of its largely produced seaweed (*Eucheuma cottoni*) potency (total production and investment opportunities), suitability for seaweed cultivation (environmental parameter and suitability), and local participation (interviews) in 2011. Seaweed production in Salabangka archipelagoes was estimated from 2009 to 2010 data. For the investment opportunities of seaweed cultivation, initial investments were assessed for the medium-scale semi refined carrageenan (SRC) model and the Carrageenan industry model. Subsequently, the profit and loss were projected for the upcoming five years. To estimate the investment qualification, several criteria were used, i.e., Net Present Value (NPV), Internal Rate Return (IRR), Net Benefit Ratio (Net B/C), Pay Back Period (PBP), and Profitability Index Methods (PI). The factors that influence the local participation and perceptions of coastal communities in Salabangka archipelagoes were analyzed based on the degree of perception and participation obtained from interviews in substation sites. The seaweed potency reveals a good prospect indicated by the increase of seaweed production and profitable investment. The environmental condition and qualifications support the suitable habitat for seaweed cultivation. Local participation shows a good indication of the support of the coastal communities. In the future, the government must secure the policy, allocate funding, and forge a partnership with the local bank to bolster the seaweed cultivation in the Salabangka archipelagoes.**

***Keywords*—Seaweed; potency; suitability; perception; Sulawesi.**

Manuscript received 21 Apr. 2021; revised 29 Oct. 2021; accepted 10 Jan. 2022. Date of publication 31 Aug. 2022.

I. Introduction

Aquaculture of seaweed has been established in Indonesia for over the decades, mainly utilizing a species of *Euchema* sp., *Gracillaria* sp., and other seaweed species [1]. As a nonfood source and main commodity (e.g., carrageenan and agar), *Euchema* sp. promises a good prospect to increase the economic growth and welfare of the coastal communities due to the advantages of easy cultivation, relatively short growing season, and low-cost production [2]. As the demands and production in this agricultural sector are increased exponentially [3], the Indonesian government has actively promoted and secured policies for the seaweed producer [4] in particular regions, including Sumatra, East Java, West Java, Bali, East Nusa Tenggara, West Nusa Tenggara, Gorontalo, Maluku, South Sulawesi, Southeast Sulawesi, and Central Sulawesi [5],[6]. However, many large coastal communities in Indonesia still live in precarious conditions despite these circumstances.

Central Sulawesi is known for the largest coastal communities with a total area of 61.841 km^2 bearing over 2.635 million population, which is considered one of Indonesia's largest seaweed producers. In contrast, many people from the coastal community still receive low income (about 23.28 % of the total population) despite the great Productivity [7]. The large production is not supported by the ability to process and add value to the product; thus, the farmers occupy the lowest rank in the value chain [8]. Salabangka archipelagoes—as the largest seaweed producer in the Morowali regency [9], have a good potential for seaweed cultivation that could improve the coastal community's welfare and enlarge the field of labor. However, the initial information for succeeding these coastal communities' empowerment in this area through seaweed cultivation is little known.

Several efforts to empower the coastal communities in Indonesia through seaweed cultivation have been initiated in many areas in Indonesia, e.g., East Java [10], Bali [2], West Nusa Tenggara [11], East Nusa Tenggara [6], Kalimantan [12], Gorontalo [13], South Sulawesi [5], [14], and Southeast Sulawesi [15], [16], [17]. Various studies have been conducted, e.g., local perceptive, market opportunities, cultivation quality, and local readiness. Hence, the first evaluation of its potency is needed to reach these goals. In this study, through the potency of seaweed *Eucheuma cottoni* (i.e., total production and investment), suitability for seaweed cultivation (environmental parameter), and local participation in the Salabangka archipelago, could provide a good understanding. Hopefully, this will expedite the empowerment effort to alleviate the poverty in the coastal communities in the Salabangka archipelagoes.

II. Materials and Methods

A. Study Areas and Time

The study was conducted on Salabangka archipelagoes, South Bungku district, Morowali regency, Central Sulawesi province, Indonesia, which comprises Tolo bay, and considered the central seaweed production (*Eucheuma cottoni*) in Morowali. Five representative study sites were chosen as a substation, i.e., Buajangka island, Kaleroang island, Waru-waru island, Bunginkela Island, and Jawi-jawi island (Fig. 1). The study was carried out starting from April – November 2011.

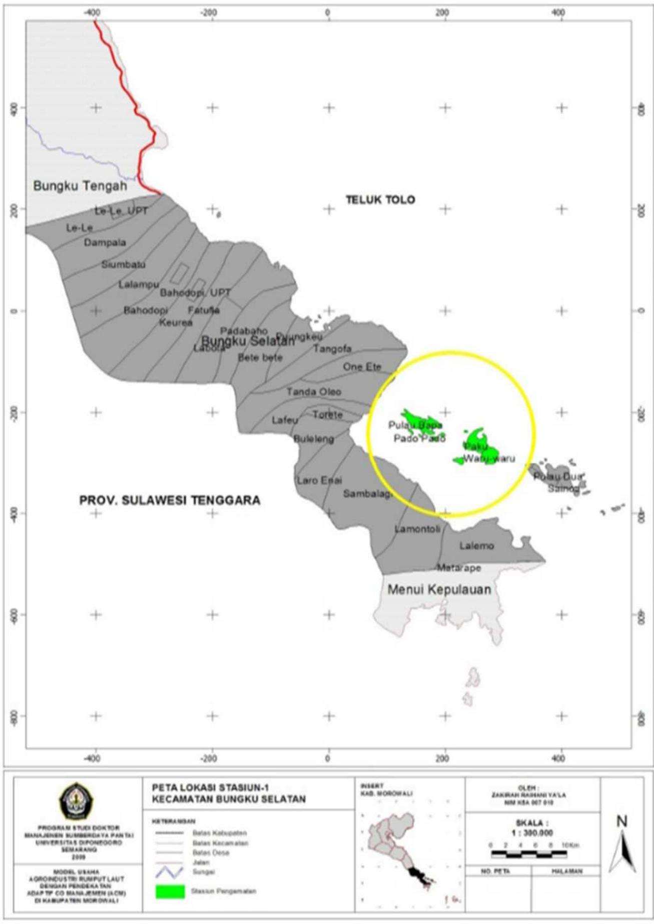


Fig. 1 Location of Salabangka archipelagoes, Morowali, Central Sulawesi, Indonesia. The study areas located in Buajangka Island, Kaleroang Island, Waru-waru Island, Bunginkela Island, and Jawi-jawi Island.

B. Estimating the Potency of Seaweed Cultivation based on Productivity and Investment

Seaweed production in Salabangka archipelagoes was estimated from 2009–2010 data and analyzed using the equation as follows:

$$Seaweed\ production\ (kg) = \Sigma\ cultivated\ area\ (ha)\ x\ \Sigma\ production\ (ton)\ x\ \Sigma\ harvesting\ time/year \quad (1)$$

To forecast the seaweed productivity in 5 years afterwards, the exponential trend analysis was used, following the recommendation of Supranto [18]. Initial investments were estimated for seaweed (*Eucheuma cottoni*) cultivation investment opportunities for the medium-scale semi refined carrageenan (SRC) and Carrageenan industry models. Subsequently, the profit and loss were projected for the upcoming five years. To estimate the investment qualification, several criteria were used, i.e. [19], Net Present Value (NPV), Internal Rate Return (IRR), Net Benefit Ratio (Net B/C), Pay Back Period (PBP), and Profitability Index Methods (PI).

NPV (the difference between the present cash inflows and present cash outflows over some time) was calculated using the equation as follows:

$$NPV = \sum_{k=0}^{n} \frac{R_k - C_k}{(1+i)^k} \quad (2)$$

IRR (investment's rate of return excluding external factors) was estimated by this equation:

$$IRR = r^2 \frac{NPV_2}{(NPV_1 - NPV_2)} r_2 - r_1 \quad (3)$$

Net B/C (the relationship between the relative costs and benefits) was estimated using this formula:

$$NetB/C = \frac{\sum_{t=0(+i)t}^{n(B_t - C_t)} - (B_t - C_1) > 0}{\sum_{t=0(+i)t}^{n(B_t - C_t)} - (B_t - C_1) < 0} \quad (4)$$

PBP (recovery time of cost investment) was calculated using this formula:

$$PBP = \frac{Cost\ of\ project}{Annual\ cash\ in\ flow} \quad (5)$$

PI (measures the value of benefits for every cost investment) was calculated using this equation:

$$PI = \frac{NPV + lo}{lo} \quad (6)$$

C. Estimating Environmental Conditions and Suitability for Seaweed Cultivation

The success of seaweed (*Eucheuma cottoni*) cultivation largely depends on the aquatic condition and environmental suitability defines as a limiting factor. The limiting factors were divided into 10 parameters, including water current (m/s), water clarity (m), water temperature (°C), total suspended solids (ppm), total dissolved solids (ppm), sea depth (m), acidity (pH), dissolved oxygen (ppm), carbon dioxide (ppm), nitrite (ppm), and phosphate (ppm), categorized based on famine season (April–May) and harvesting season (June–July). Fifteen sites were sampled according to the adjacent five representative study sites.

D. Indicating Local Participation of Coastal Communities

The factors that influence the local participation and perceptions of coastal communities in Salabangka archipelagoes were analyzed based on the degree of perception and participation obtained from interviews in substation sites. Likert scales were used to categorize the scoring of the respondent's answers [20]. The perception is divided into four categories, i.e., the chosen cultivation area, seaweed management, capabilities of coastal communities, and coastal community participation.

III. RESULTS AND DISCUSSION

A. The Potency of Eucheuma Cottoni based on Production and Investment Opportunities

The mean production value of seaweed of Salabangka archipelagoes in 2009 reached up to 2.4 ton/ha (Fig. 2). In January–March, it shows no production at all. The harvested seaweed was barely started in April, even though the capacity is not entirely effective. Then, the increase of seaweed production increased exponentially in April–May.

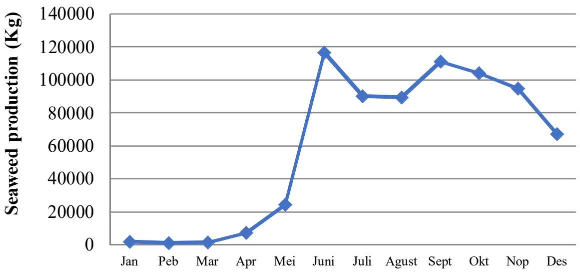


Fig. 2 Seaweed (*Eucheuma cottoni*) production of Salabangka archipelagoes in 2009

In 2010, there was an increase in Seaweed (*Eucheuma cottoni*) production by as much as 35% (3.1 ton/ha) compared to the previous year (Fig. 3). The production increased exponentially in June–October, in which the farmer enlarges the seaweed cultivation area. However, there was a gradual decrease in production in November–December. Subsequently, production stopped in January– March.

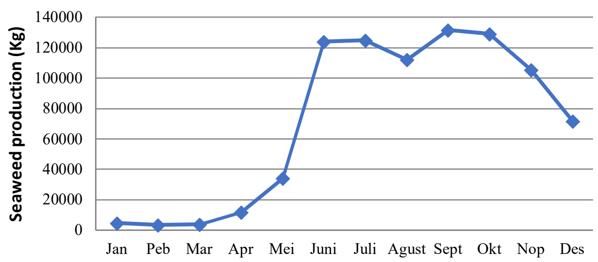


Fig. 3 Seaweed (*Eucheuma cottoni*) production of Salabangka archipelagoes in 2010

Exponential trend analysis predicts that the Seaweed *Eucheuma cottoni* production will increase from 2011 to 2015 (Fig. 4).

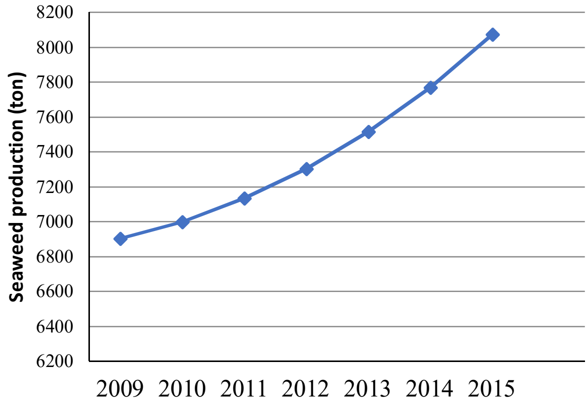


Fig. 4 Seaweed (*Eucheuma cottoni*) production of Salabangka archipelagoes in 2010

For the initial investment, a total of IDR. 917,000,000, - for SRC model (Table 1) and IDR.1,379,500,000, - for Carrageenan industry model (Table 2), were estimated.

TABLE I
THE INITIAL INVESTMENT FOR THE MIDDLE-SCALE SEMI REFINE CARRAGEENAN (SRC) MODEL IN SALABANGKA ARCHIPELAGOES

Specification	Detail Unit	Total Unit	Unit Price (IDR)	Total Value (IDR)
Land and buildings				
Land surface (m²)	2,000	1	15,000	30,000,000
Land for processing building (m²)	200	200	2,000,000	400,000,000
Land for warehouse	100	50	1,500,000	75,000,000
Transportation unit (Minibus)		1	150,000,000	150,000,000
Office supplies		2	10,000,000	20,000,000
Sofa		1	1,000,000	1,000,000
Conferences tables		1	1,500,000	1,500,000
Computer & Printer		1	6,000,000	6,000,000
Calculator		2	250,000	500,000
Seaweed washing container	200 liters	2	1,000,000	2,000,000
Medium blender	10 kg/h	2	10,000,000	20,000,000
Cooking pot	200 liters	2	7,000,000	14,000,000
Weighing tool	25 kg	1	2,500,000	2,500,000
Paste coriander	60 mesh	1	155,000,000	155,000,000
Mixing tub	50 liters	2	8,500,000	17,000,000
Drying oven		1	12,500,000	12,500,000
Flouring machine		1	2,000,000	2,000,000
High-pressurize pot		2	1,500,000	3,000,000
Equipment quality kit		1	5,000,000	5,000,000
TOTAL VALUE (IDR)				**917,000,000**

TABLE II
THE INITIAL INVESTMENT FOR THE CARRAGEENAN INDUSTRY MODEL IN SALABANGKA ARCHIPELAGOES

Specification	Detail Unit	Total Unit	Unit Price (IDR)	Total Value (IDR)
Land and buildings				
Land surface (m²)	2,000	2,000	15,000	30,000,000
Land for processing building (m²)	200	200	3,500,000	700,000,000
Land for warehouse	100	100	1,500,000	150,000,000
Transportation unit (Minibus)		2	150,000,000	300,000,000
Office Supplies		4	15,000,000	60,000,000
Sofa		1	2,000,000	2,000,000
Conferences tables		1	1,500,000	1,500,000
Computer & Printer		1	6,000,000	6,000,000
Calculator		2	250,000	5,000,000
Seaweed washing container	200 liters	2	1,000,000	2,000,000
Medium blender	10 kg/h	2	18,000,000	36,000,000
Cooking pot	200 liters	2	10,000,000	20,000,000
Weighing tool	25 kg	1	2,500,000	2,500,000
Paste coriander	60 mesh	1	15,500,000	15,500,000
Mixing tub	50 liters	2	8,500,000	17,000,000
Drying oven		1	20,000,000	20,000,000
Flouring machine		1	4,000,000	4,000,000
High-pressurize pot		2	1,500,000	3,000,000
Equipment quality kit		1	5,000,000	5,000,000
TOTAL VALUE (IDR)				**137,950,000**

For the production cost, a total of IDR. 170,980,499, - per month for the SRC model (Table 3), and IDR. 142,980,358, - per month for the Carrageenan industry model (Table 4) were estimated if it worked on 100% production capacity.

TABLE III
THE PRODUCTION COST FOR MIDDLE-SCALE SEMI REFINE CARRAGEENAN (SRC) IN SALABANGKA ARCHIPELAGOES

Specification	Detail Unit	Unit Price (IDR)	Total Value (IDR)
Seaweed (kg)	8,333	12,000	99,996,000
Buffer salt KOH (kg)	167	20,000	3,340,000
Kerosene fuel (litre)	1,000	6,000	6,000,000
Wrapping ingredient (sheet)	83	9,000	747,000
Salary for Staff			
Executive manager	1	4,000,000	4,000,000
Production manager	1	2,500,000	2,500,000
Marketing manager	1	2,500,000	2,500,000
Personalia manager	1	2,500,000	2,500,000
Administration manager	1	2,500,000	2,500,000
Staff	30	1,400,000	42,000,000
Tax for building and land			20,833.3
Tax for service and permit			166,666.7
Equipment shrinkage			4,709,999.23
Total Value (IDR)			**170,980,499**

TABLE IV
THE PRODUCTION COST (IDR) FOR THE CARRAGEENAN INDUSTRY IN SALABANGKA ARCHIPELAGOES

Specification	Detail Unit	Unit Price (IDR)	Total Value (IDR)
Seaweed (kg)	8,333	8,425	70,205,525
Buffer salt KOH (kg)	167	16,000	544,000
Kerosene fuel (litre)	1,000	4,000	10,000,000
Wrapping ingredient (sheet)	83	8,000	1,200,000
Salary for Staff			
Executive manager	1	4,000,000	4,000,000
Production manager	1	2,500,000	2,500,000
Marketing manager	1	2,500,000	2,500,000
Personalia manager	1	2,500,000	2,500,000
Administration manager	1	2,500,000	2,500,000
Staff	30	1,400,000	42,000,000
Tax for building and land			20,833.3
Tax for service and permit			166,666.7
Equipment shrinkage			4,843,332.77
Total Value (IDR)			**142,980,358**

The profit-loss projection for both the SRC model and the Carrageenan industry model was summarized as follows: the first year would operate at 60% production capacity, and increase to 70% in the second year, 80% in the third year, and finally, 100% in the fourth and fifth year. The projected profit-loss shows that the cash flow on the SRC model (Table 5) and Carrageenan industry model (Table 6) had a negative value in the first year. However, an increase in balance was observed in the third to the fifth year.

The estimation of investment qualification based on PBP, Net B/C ratio, IRR, and PI (Table 7) shows that both the SRC model and the Carrageenan industry model show an acceptable prospect. SRC model reaches the cost recovery faster (i.e., 2 years 9 months) than the Carrageenan industry model (i.e., 3 years 5 months). NPV shows a positive value, while IRR was estimated above the tax interest. The PI value, which reaches 2.95, shows that this business model is worth investment.

In Indonesia, small-scale farmers operate seaweed farming, utilizing small capital and short harvest time [21], and the government has overlooked this operation. The study reveals that these small-scale operations could benefit families and communities [22]. However, the fund source for this business model in Salabangka archipelagoes still originated from loan sharks, which applied a high-interest rate, compounded by the dysfunctionality of the local union of seaweed agriculture in that region. The government must act immediately to form a policy to promote and bolster seaweed cultivation. To implement this model and reach the goal effectively, the government must allocate capital in the form of a grant fund or revolving fund that could accommodate the farmer. It could be channeled through the local or national government budget. The government also needs to secure the policy and forge a partnership with the local bank. This way, the farmer could access the fund easily.

TABLE V
PROJECTED PROFIT-LOSS (IDR) IN 2011-2015 FOR MIDDLE-SCALE SEMI REFINE CARRAGEENAN (SRC) MODEL IN SALABANGKA ARCHIPELAGOES

No	Specification	1st year	2nd year	3rd year	4th year	5th year
1	Income	1,440,000,000	2,160,000,000	3,000,000,000	3,300,000,000	3,600,000,000
2	Operational cost					
	Variable cost					
	Seaweed	600,000,000	880,000,000	1,200,000,000	1,300,000,000	1,400,000,000
	Buffer salt KCL	21,600,000	26,600,000	40,000,000	42,000,000	44,000,000
	Fuel	36,000,000	52,800,000	72,000,000	78,000,000	84,000,000
	Wrapping ingredients	4,800,000	6,800,000	9,000,000	9,500,000	10,000,000
	Fix cost					
	Equipment renewal		5,000,000	10,000,000	10,000,000	15,000,000
	Executive manager salary	48,000,000	54,000,000	60,000,000	66,000,000	72,000,000
	Production manager salary	30,000,000	31,800,000	33,600,000	33,600,000	39,000,000
	Marketing manager salary	30,000,000	31,800,000	33,600,000	33,600,000	39,000,000
	Personalia manager salary	30,000,000	31,800,000	33,600,000	33,600,000	39,000,000
	Administration manager salary	30,000,000	31,800,000	33,600,000	33,600,000	39,000,000
	Staff salary	504,000,000	540,000,000	567,000,000	567,000,000	630,000,000
	Tax for building and land	250,000	250,000	250,000	250,000	250,000
	Tax for service and permit	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
	Equipments shrinkage	56,519,990.76	56519,990.76	56,519,990.76	56,519,990.76	56,519,990.76
3	Income and Operational Cost	1,393,169,991	1,751,169,991	2,151,169,991	2,265,669,991	2,469,769,991
4	Net profit before tax and interest	46,830,009.24	408,830,009	848,830,009	1,034,330,009	1,130,230,009
5	Interest cost (16%)	146,720,000	146,720,000	146,720,000	146,720,000	146,720,000
6	Profit before tax	-99,889,990.76	262,110,009.2	702,110,009.2	887,610,009.2	983,510,009.2
7	Tax on PPh (15%)	7,024,501.4	61,324,501.4	127,324,501	155,149,501.4	169,531,501.4
8	Net profit	-106,914,492.2	200,785,507.8	574,785,508.2	732,460,507.8	813,978,507.8
9	Net balance	48,467,499	357,017,499	679,665,500	888,692,500	970,207,499.5

TABLE VI
PROJECTED PROFIT-LOSS (IDR) IN 2011-2015 FOR CARRAGEENAN INDUSTRY MODEL IN SALABANGKA ARCHIPELAGOES

No	Specification	1st year	2nd year	3rd year	4th year	5th year
1	Income	1,500,000,000	2,400,000,000	3,500,000,000	4,000,000,000	4,500,000,000
2	Operational cost	1,500,000,000	2,400,000,000	3,500,000,000	4,000,000,000	4,500,000,000
	Variable cost					
	Seaweed	600,000,000	880,000,000	1,200,000,000	1,300,000,000	1,400,000,000
	Buffer salt KCL	3,840,000	5760,000	8,000,000	8,800,000	9,600,000
	Fuel	90,000,000	130,680,000	180,000,000	195,000,000	210,000,000
	Wrapping ingredients	6,000,000	8,280,000	16,200,000	17,100,000	18,000,000
	Fix cost					
	Equipment renewal		10,000,000	10,000,000	20,000,000	20,000,000
	Executive manager salary	48,000,000	59,400,000	60,000,000	66,000,000	72,000,000
	Production manager salary	30,000,000	33,000,000	36,000,000	39,000,000	42,000,000
	Marketing manager salary	30,000,000	33,000,000	36,000,000	39,000,000	42,000,000
	Personalia manager salary	30,000,000	33,000,000	36,000,000	39,000,000	42,000,000
	Administration manager salary	30,000,000	33,000,000	36,000,000	39,000,000	42,000,000
	Staff salary	504,000,000	396,000,000	576,000,000	612,000,000	648,000,000
	Tax for building and land	250,000	250,000	250,000	250,000	250,000
	Tax for service and permit	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
	Equipments shrinkage	58,119,993.24	58,119,993.24	58,119,993.24	59,119,993.24	58,119,993.24
3	Income and Operational Cost	1,432,209,993	1,672,489,993	2,254,569,993	2,436,269,993	2,605,969,993
4	Net profit before tax and interest	67,790,006.76	727,510,006.8	1,245,430,007	1,563,730,007	1,894,030,007
5	Interest cost (16%)	220,720,000	220,720,000	220,720,000	220,720,000	220,720,000
6	Profit before tax	-152,929,993.2	506,790,006.8	1,024,710,007	1,343,010,007	1,673,310,007
7	Tax on PPh (15%)	-22,939,498.99	109,126,501	186,814,501	234,559,501	284,104,501
8	Net profit	-175,869,492	397,663,505.7	837,895,505.7	1,108,450,506	1,389,205,506
9	Net balance	-944,681,424	643,395,498.7	1,083,627,499	1,354,182,499	1,634,937,499

TABLE VII
INVESTMENT OPPORTUNITY FOR MIDDLE-SCALE SEMI REFINE CARRAGEENAN (SRC) MODEL AND CARRAGEENAN INDUSTRY MODEL IN SALABANGKA ARCHIPELAGOES

Investment criteria	Business model	
	SRC	Carrageenan industry
Payback periods (PBP)	2 year, 9 month	3 year, 5 month
Net Benefit Cost Ratio (NetB/C ratio)	1.35	1.88
Net Present Value (NPV)	IDR. 1,786,785,601	IDR. 2,690,243,917
Internal Rate of Return (IRR)	35%	33.93%
Profitability Index (PI)	2.94	2.95

B. Environmental Conditions and Suitability for Seaweed Cultivation

The environmental conditions support seaweed cultivation in Harvest Season (June – July) (Table 8). For instance, the strong water current of (0.11 – 0.17 m/s) (Table 8) could hold a better condition for seaweed cultivation [23] by providing a barrier and nutrition that is essential for seaweed development. The degree of water clarity reveals that the light, which is essential for seaweed photosynthesis, can penetrate through the water (around 2.00 – 4.6 m) (Table 8). The suitable temperature for *Eucheuma cottoni* ranges from 26 – 33^{o}C [24], which is also reflected in both seasons (Table 8). The suitable range of total suspended solid for *Eucheuma cottoni* cultivation is around <25 ppm [25]. Based on this parameter, both seasons show a proper condition for *Eucheuma cottoni* cultivation (Table 8) since the higher level of TSS could prevent the natural light from penetrating the seafloor. A high degree of differences in the total dissolved solid parameter was also observed (Table 8). However, it is still considered suitable, below the lowest threshold < 80 ppm [23]. The suitable depth for seaweed cultivation must be less than 10 meters above the sea ground [23], and both seasons show a roughly suitable condition (Table 8). For the acidity, as previously stated by Poncomulyo et al. [23], the optimum acidity (pH) for seaweed cultivation is around 7.3–8.2, and both seasons fall under this range (Table 8). The dissolved oxygen, essential for aquatic organism respiration, also shows a good range in both seasons (Table 8). If the span falls below 4 ppm, it indicates extreme perturbances to the aquatic ecosystem [26]. The nitrite content originating from industrial, or community waste shows an unsuitable condition during harvest season due to the high nitrate content (16.97 ppm) (Table 8). Akhter et al. [27] stated that the average amount of nitrite in seawater must fall between 0.5 – 3 ppm. The high nitrate content might be due to the east season, which carries organic material from the human settlement after the heavy rain and later accumulated nitrite on the sea. As an essential nutrient for an aquatic organism, the phosphate parameter shows a suitable condition (Table 8). Widianingsih et al. [28] stated that the phosphate content must fall between 0.02 – 1 ppm. Summarizing all of these limiting factors, it can be concluded that the harvest season time yields a suitable condition for seaweed *Eucheuma* cultivation in the Salabangka archipelagos (Table 8).

TABLE VII
ENVIRONMENTAL CONDITIONS BASED ON LIMITING FACTORS AND SUITABILITY OF SEAWEED CULTIVATION IN SALABANGKA ARCHIPELAGOES

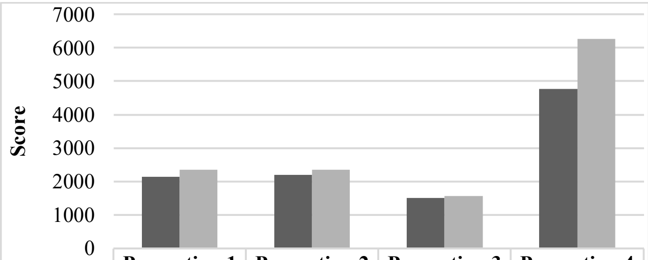
No.	Limiting factors	Famine season (April–May)	Harvest season (June–July)
		Range	
1	Water current (m/s)	0.05 – 0.02	0.11 – 0.17
2	Water clarity (m)	1.7 – 4.4	2.00 – 4.6
3	Water temperature (^{o}C)	29.0 – 32.0	28.3 – 30.0
4	Total suspended solid (ppm)	1.26 – 14.31	1.16 – 7.35
5	Total Dissolved solid (ppm)	27.26 – 54.08	50.27 – 51.16
6	Sea depth (m)	0.01 – 0 .05	1.05 – 18.6
7	Acidity (pH)	7.9 – 8.7	7.7 – 8
8	Dissolved oxygen (ppm)	6.8 – 9.84	7.1 – 9.83
9	Nitrite (ppm)	0.88 – 2.2	0.48 – 16.97
10	Phosphate (ppm)	0.07 – 0.30	0.03 – 0.35
	Physic-Chemical categorization	**Suitable**	**Not Suitable**

The environment was one of the crucial factors in seaweed cultivation's success and increased human well-being. Seaweed farming could contribute a positive impact on the environment. A previous study found that the construction of seaweed farms correlated to increased seagrass habitat [29]. Another study also found that the rate of mangrove loss is reduced along with the initiation of aquaculture farms [30]. Several studies have found a positive correlation between seaweed farming to the population of ratfish [31] and the reduction of some fishing [32]. Knowing the good indication of these limiting factors aforementioned and effective implementation of such aquaculture could facilitate increased environmental and well-being quality.

C. Local Participation of Coastal Communities

Based on the local perception (Fig. 5), Perception 1, defined as local support for the seaweed cultivation area, reached 2,143 positive reinforcements out of 2,352 respondents (91.11%). Perception 2, defined as local support on seaweed management, reached 2,193 positive supports out of 2,352 respondents (93.23%) (Fig. 5). Perception 3, defined as local support on community capabilities, reached 1,503 positive supports out of 1,568 respondents (95.85%). Perception 4 represents local support as participation, come 4,767 positive reinforcements out of 6,272 respondents (76%) (Fig. 5). Overall, the perception and participation of coastal communities show that they support the empowerment effort through Seaweed cultivation.

The local participation concept is highly associated with transparency, to say that the coastal communities would participate if the government accounted for integrity and transparency. By this concept, the people also have the right to the decision along with the government. The institutional arrangement [33], local decision-making rights and capacity [34], and social sustainability [35] are necessary to accomplish these goals in the future.



	Perception 1	Perception 2	Perception 3	Perception 4
Score	**2143**	**2193**	**1503**	**4767**
Total	**2352**	**2352**	**1568**	**6272**

Fig. 5 Scoring of local participation toward Seaweed production empowerment in Salabangka archipelagoes. Perception 1 = cultivation area, Perception 2 = seaweed management, Perception 3 = community capabilities, Perception 4 = community participation.

IV. CONCLUSION

Coastal community's empowerment in Salabangka archipelagoes through Seaweed (*Eucheuma cottoni*) cultivation promises good opportunities. From the perspective of its potency, it shows an increase in Productivity in the year afterwards and a profitable prospect for future investment. The environmental condition also indicates a good qualification for seaweed cultivation. The local participation shows that they support the empowerment effort through the Seaweed Eucheuma cultivation. However, the government must secure the policy, allocate funding, and forge a partnership with the local bank to bolster the seaweed cultivation in Salabangka archipelagoes.

ACKNOWLEDGMENT

The authors thank Tadulako University for facilitating this research.

REFERENCES

[1] A. Q. Hurtado, P. E. Lim, J. Tan, S. M. Phang, I. C. Neish, and A. T. Critchley, *Biodiversity and biogeography of commercial tropical carrageenophytes in the southeast Asian region. Carrageenans: sources and extraction methods, molecular structure, bioactive properties and health effects*. Hauppauge, New York: Nova Science Publishers, 2016, pp. 67-90.

[2] A. H Buschmann, C. Camus, J. Infante, A. Neori, Á. Israel, M. C. Hernández-González, S. V. Pereda, J. L. Gomez-Pinchetti, A. Golberg, N. Tadmor-Shalev, and A. T. Critchley, "Seaweed production: overview of the global state of exploitation, farming and emerging research activity," *Eur. J. Phycol.*, vol. 52, no. 4, pp. 391-406, Oct. 2017, doi: 10.1080/09670262.2017.1365175.

[3] Food Agriculture Organization Fisheries and Aquaculture Information and Statistics Branch (FAO-FIGIS). (2019, Dec 17). *FIGIS-Time series query on Aquaculture*. [Online]. Available: http://www.fao.org/figis/servlet/SQservlet.html

[4] National Legislation: Undang-Undang Republik Indonesia No.7 tahun 2016. *Perlindungan dan pemberdayaan nelayan, pembudidaya ikan, dan petambak garam*, Jakarta, 2016, pp. 1–48. [In Indonesian]

[5] A. Zamroni, and M. Yamao, "Coastal resource management: fishermen's perceptions of seaweed farming in Indonesia," *World Acad. Sci. Eng. Technol.*, vol. 60, pp. 32-38, Jan. 2011.

[6] M. Mariño, A. Breckwoldt, M. Teichberg, A. Kase, and H. Reuter, "Livelihood aspects of seaweed farming in Rote Island, Indonesia" *Mar. Pol.*, vol. 107, pp. 103600, Sept. 2019, doi: 10.1016/j.marpol.2019.103600.

[7] Badan Pusat Statistik (BPS). (2010a) Kabupaten Morowali Dalam Angka. Badan Pusat Statistik Provinsi Sulawesi Selatan. [In Indonesian]

[8] P. Nakhate, and Y. van der Meer, "A Systematic Review on Seaweed Functionality: A Sustainable Bio-Based Material," *Sustainability*, vol. 13, no. 11, pp. 6174, May 2021, doi: 10.3390/su13116174

[9] Badan Pusat Statistik (BPS) Statistics Indonesia. (2010). *Kecamatan Bungku Selatan Dalam Angka*. Sulawesi Selatan: Badan Pusat Statistik Provinsi. [In Indonesian]

[10] S. Sriwulandari, H. Wahyono, S. M. Widjaja, and S. H. Utomo, "Enhancement of Market Opportunities for Seaweed Farmers: East Java in Indonesia/Mejoramiento de las oportunidades de mercado para los productores de algas marinas: Java Oriental en Indonesia," *Utopía y Praxis Latinoamericana*, vol. 25, no. S6, pp. 114-122, Aug. 2020, 10.5281/zenodo.3987584.

[11] A. Zamroni, "Small scale entrepreunership of seaweed in Serewe Bay, East Lombok, Indonesia: Challenges and Opportunities," *J. Dev. Agric. Econ.*, vol. 10, no. 5, pp. 165-175, May 2018, 10.5897/JDAE2017.0874.

[12] D. A. Lestari, D. Susiloningtyas, and T. Handayani, "Potential Region for development of seaweed genus Eucheuma cottonii based on ENSO variability in east coast of Tarakan Island, Indonesia," *IOP Conf. Ser.: Earth Environ. Sci.*, vol. 284, no. 1, pp. 012030, May 2019, 10.1088/1755-1315/284/1/012030.

[13] S. Kamuli, and B. Amin, "Women and Organizational Capabilities in Seaweed Production in North Gorontalo," *MIMBAR: Jurnal Sosial dan Pembangunan*, vol. 34, no. 1, pp. 1-10, Jun. 2018, 10.29313/mimbar.v34i1.2764.

[14] S. Larson, N. Stoeckl, M. E. Fachry, M. D. Mustafa, I. Lapong, A. H. Purnomo, M. A. Rimmer, and N. A. Paul, "Women's well-being and household benefits from seaweed farming in Indonesia. *Aquaculture*, vol. 530, pp. 735711, Jan. 2020, 10.1016/j.aquaculture.2020.735711.

[15] M. A. Limi, L. Sara, T. La Ola, L. Yunus, S. A. A. Taridala, H. Batoa, A. Hamzah, S. A. Fyka, and M. Prapitasari, "The production and income from seaweed farming after the sedimentation in Kendari Bay," *AACL Bioflux*, vol. 11, no. 6, pp. 1927-1936, Dec. 2018.

[16] H. Rokhani, and J. Siti, "Seaweed business development strategy in Buton Regency, Southeast Sulawesi of Indonesia," *Russ. J. Agric. Socio-Econ. Sci.*, vol. 83, no. 11, Nov. 2018, doi: 10.18551/rjoas.2018-11.42.

[17] A. A. Muthalib, A. Putera, W. A. Rumbia, P. Adam, A. M. Nuryadi, A. B. Wawo, and M. Nur, "An empowerment model of seaweed farmers in coastal area of Southeast Sulawesi, Indonesia," *AACL Bioflux*, vol. 12, no. 6, pp. 2252-2260, 2019.

[18] J. Supranto, *Metode ramalan kuantitatif untuk perencanaan*. Jakarta: Gramedia, 2000, pp. 212-220. [In Indonesian]

[19] N. Lemeshko, "Analysis and estimation of effectiveness of investment projects," *Technol. Audit Prod. Reserv.*, vol. 2, no. 4, pp. 9-14, March 2017, 10.15587/2312-8372.2017.98189.

[20] D. Kriksciuniene, V. Sakalauskas, and R. Lewandowski, "Evaluating the Interdependent Effect for Likert Scale Items," in *Business Information Systems Workshops*, W. Abramowicz, and R. Corchuelo, Ed. Switzerland: Springer Nature Switzerland AG, pp. 26–38, 2019.

[21] S. Larson, N. Stoeckl, M. E. Fachry, M. D. Mustafa, I. Lapong, A. H. Purnomoe, M. A. Rimmera, and N. A. Paul, "Women's well-being and household benefits from seaweed farming in Indonesia, "*Aquaculture*, vo. 530, no. 735711, pp. 1-8, Jul. 2020, doi: 10.1016/j.aquaculture.2020.735711

[22] K. A. Krumhansl, J. N. Bergman, and A. K. Salomon, "Assessing the ecosystem-level consequences of a small-scale artisanal kelp fishery within the context of climate-change," *Ecol. Appl.*, vol. 27, no. 3, pp. 799-813. Apr. 2017, doi: 10.1002/eap.1484.

[23] D. Sulistiawati, Z. R. Ya'la, J. Jumiyatun, and Z. Mubaraq, "Water quality study in several seaweeds culture sites in the postearthquake-tsunami Palu Central, Sulawesi Province," *J. Physic: Conf Ser.*, vol. 1434, no. 102035, pp. 1-11, doi:10.1088/1742-6596/1434/1/012035.

[24] Z. R. Ya'la, D. Sulistiawati, M. Masyahoro, and Nasmia, "Seaweed (Eucheuma cottonii) growth in polyculture application," *AACL Bioflux*, vol. 10, no. 5, pp. 1064-1073, Sep. 2017.

[25] N. Nasmia, S. Natsir, E. Rosyida, R. Rusaini, and Z. R. Ya'la, "Toxicity of liquid extract of seaweed *Sargassum* sp. on the growth of microalgae *Skeletonema costatum*," *AACL Bioflux*, vol. 10, no. 2, pp. 247-253, Apr. 2017.

[26] M. L. Brusseau, I. L. Pepper, and C. P. Gerba, *Environmental and Pollution Science*, 3th Edition. USA: Elsevier B.V., 2019, doi: 10.1016/C2017-0-00480-9

[27] F. Akhter, H. R. Siddiquei, M. E. E. Alahi, and S. C. Mukhopadhyay, "*Recent Advancement of the Sensors for Monitoring the Water Quality Parameters in Smart Fisheries Farming*," *Computers*, vol. 10, no. 26, pp. 1-20, doi: 10.3390/computers10030026.

[28] W. Widianingsih, R. A. T. Nuraeni, R. Hartati, H. Endrawati, D. N. Sugianto, and R. T. Mahendrajaya, "Water quality in the ecosystem of

sea cucumber Acaudina sp. in the Delta Wulan Waters, Central of Java," *IOP Conf. Ser: Earth Environ. Sci*., vol. 744, no.012097, pp. 1-9, May 2021, doi:10.1088/1755-1315/744/1/012097

[29] A. Moreira-Saporiti, D. Hoeijmakers, F. E. Msuya, H. Reuter, and M. Teichberg, "Seaweed farming pressure affects seagrass and benthic macroalgae dynamics in Chwaka Bay (Zanzibar, Tanzania)," *Reg. Environ. Change*., vol. 21, no. 11, pp. 1-12, Jan. 2021, doi: 10.1007/s10113-020-01742-2.

[30] L. Goldberg, D. Lagomasino, N. Thomas and T. Fatoyinbo, "Global declines in human-driven mangrove loss," *Glob. Change. Bio.*, vol. 26, no. 0, pp. 5844-5855, Oct. 2020, doi: 10.1111/gcb.15275.

[31] E. J. Hehre, and J. J. Meeuwig, "A global analysis of the relationship between farmed seaweed production and herbivorous fish catch," *PloS one*, vol. 11, no. 2, pp. e0148250, Feb. 2016, doi: 10.1371/journal.pone.0148250.

[32] N. A. Hill, J. M. Rowcliffe, H. J. Koldewey, and E. J. Milner-Gulland, "The interaction between seaweed farming as an alternative occupation and fisher numbers in the Central Philippines," *Conserv. Biol*., vol. 26, no. 2, pp. 324-334, Nov. 2012, doi: 10.1111/j.1523-1739.2011.01796.x.

[33] A. H. Purnomo, S. Subaryono, B. S. B. Utomo, and N. Paul, "Institutional arrangement for quality improvement of the Indonesian Gracilaria seaweed," *AACL Bioflux*, vol. 13, no. 5, pp. 2798-2806, 2020.

[34] D. J. Steenbergen, C. Marlessy, and E. Holle, "Effects of rapid livelihood transitions: examining local co-developed change following a seaweed farming boom," *Mar. Pol*., vol. 82, pp. 216-223, Aug. 2017, 10.1016/j.marpol.2017.03.026.

[35] G. A. S. Ginigaddara A. I. Y. Lankapura, L. P. Rupasena, and A. M. K. R. Badara, "Seaweed farming as a sustainable livelihood option for northern coastal communities in Sri Lanka," *Future Food: J. Food Agric. Soc.*., vol. 6, no. 1, pp. 57-41, Dec. 2018.