Analysis of Salt Production in Crystallization Houses Integrated with Grouper Cultivation

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Abstract

This study aims to assess the efficacy of a model innovation in enhancing both the quality and quantity of salt production in the Lekok District, Pasuruan Regency. The innovation involves integrating salt production with grouper cultivation within the crystallization house. The salt production process in this innovation utilizes filters to expedite the precipitation of impurities from seawater, which serves as the raw material. Data collection took place during both the dry and rainy seasons. In the dry season, the salt produced using a filter achieved the highest quality, designated as K1, whereas the salt produced without a filter was of K2 quality. In the rainy season, filtered and unfiltered production yielded salt of K3 quality. Nevertheless, this represents a significant advancement since salt production was previously impeded during the rainy season due to adverse weather conditions. The Return on Investment (ROI) for salt production is approximately 106.46%, and according to the Cost Benefit Environment Analysis, the salt production process is environmentally friendly. Consequently, implementing salt production innovations in the crystallization house, and utilizing filters, holds promise for augmenting the income of coastal communities in the Lekok District, Pasuruan Regency.

Keywords: Salt Production, Integrated Innovation, Sea Water Filtration

1. Introduction

The poverty rate in the coastal area of Pasuruan Regency is the highest compared to the poverty rate outside the coastal area. Based on BPS (Badan Pusat Statistik) data for Pasuruan Regency 2019, there were 141,000 people in Pasuruan Regency, or 8.68% living in poverty. The number of poverties in coastal areas proves that managing marine resources is not optimal. If appropriately managed, marine resources have enormous potential and can have high economic value. Poverty is influenced by many factors, including natural, structural, and cultural factors [1]. Natural factors are natural conditions at sea that are very unpredictable such as high waves, strong winds, and storms. Structural problems of coastal communities include weak capitalization, being trapped by intermediaries and loan sharks, and technology limitations [2]. The cultural factor is that coastal communities often hold rituals at great expense.

Development of coastal areas, such as the procurement of beach tourism, management of mangrove forests, and cultivating with a pond system, affect the welfare of coastal communities [3]. Pond cultivation is a brackish water cultivation activity with artificial ponds in coastal areas. Meanwhile, intercropping comprises integrated activities between fish farming and planting, maintenance, management, and preservation of mangrove forests [4].

The pattern of the intercropping approach is mainly carried out in coastal areas with mangrove forests. [5] researched tiger grouper (*Epinephelus fuscoguttatus*) intercropping cultivation in mangrove areas. In comparison, [5] developed intercropping in the coastal area of Arakan Village, Tatapaan District, South

Minahasa Regency. However, these activities are only sometimes successful in some coastal areas because the local potentials are different.

According to [6] and [7], apart from being based on local potential, coastal areas' development, and management must align with the coastal communities' actual conditions. The strategy needed in the management of coastal areas is community-based management. Based on identifying the potential of many coastal areas in Indonesia, seawater as raw material for salt has excellent potential, including in Lekok District, Pasuruan Regency. However, using seawater to become the raw salt material can only be carried out by fishermen with ponds. Producing salt in Indonesia is carried out in the Sustainable Food Home Area (KRPL), as is done by a small number of coastal communities in Lekok District, Pasuruan Regency. Lekok District has considerable potential; there is a fish auction place with an average fish catch of one to two tons daily.

[8] combine salt production with farming. It is managed by applying the concept of integrated management between corporate farming, collective farming, and cooperative farming. [9] seek to increase salt production by expanding salt ponds and socializing production factors appropriately and proportionally. Due to the lack of pond land, efforts to expand salt pond land cannot be implemented in Lekok District. An innovation in salt production, namely Rumah Prisma (Prism Houses), can be applied to increase salt production. Innovation is proven to produce good-quality salt [10].

As the condition of the pond area in Lekok District continues to decrease, there is a high need for salt and a lot of fish farming; therefore, in this study, an assessment was carried out on the intercropping model of salt production in prism houses with grouper cultivation.

2. Materials and Methods

Experimental site

The research location was in the coastal area of Lekok District, Pasuruan Regency. During the dry season, the people in the coastal area of Lekok District carry out salt production traditionally. However, during the rainy season, people can only farm as a livelihood due to weather constraints.

The research was conducted from May 2022 to December 2022 by creating an innovative model for salt production using a grouper cultivation intercropping system. The model is 12 m^2 in size. Seawater as a raw material for making salt and a mixture for fish farming is taken directly from the sea and placed in a banker.

Experimental design

Figure 1 Experimental design of salt production

Seawater for the salt production process will go through two filtrations. Filtration aims to filter out impurities to improve the quality of raw salt water. The filter consists of (1) coconut and palm fiber as an anti-bacterial purifier. (2) coconut shell charcoal to remove taste and odor in water, (3) coral fragments to reduce impurities and metal content, (4) zeolite to reduce Ca and Mg content, and (5) sponge as a filter with a minor cavity that functions to filter out particles that pass from the previous layer.

Sampling

Data were collected from May to December 2022 by conducting periodic tests of salinity, temperature, pH, and water cleanliness (TDS) on original seawater, brines, and bittern. Furthermore, salt produced from the two seasons is also collected. Laboratory tests are carried out to determine the percentage of Ca, NaCl, water content, and Mg, and the quality of salt according to Indonesian National standards.

Data analysis

Data is analyzed and combined with quantitative data and qualitative data from research. Qualitative methods are carried out to measure the quality of salt produced, including NaCl percentage, size, and color. Some standard laboratory analysis methods were used to analyze the quality of salt. At the same time, the quantitative method is carried out to measure the quantity of salt produced to meet the salt needs of coastal communities in the Lekok District. Measurement of the feasibility of salt production with a model is carried out using the method of cost-benefit analysis and cost-benefit environment analysis.

3. Results

The parameters measured in this study are the original seawater content on the coast of Lekok District. The following table shows that seawater is usually used as a raw material for producing salt.

Table 1 Parameters of the seawater

No	Parameter	Unit	Parameter Value		
			Sample 1	Sample 2	Sample 3
1.	Temperature	^0C	27,9	28,4	28,7
2.	Salinity	PPT	27	29	30
3.	PH	-	7,61	7,54	7,5
4.	TDS	mg/L	$11,4 \times 10^{-9}$	$12,7 \times 10^{-9}$	$14,9 \times 10^{-9}$

From the observations, it was found that the salinity of seawater in the three villages closest to the research location in the waters of Lekok District was different. The difference is influenced by rivers around the coast or drainage channels from human activities that end up in the sea. It is well known that on the coast of Tambak Lekok District (sample 1), there is an estuary of a river that discharges human activities with a very dense population, namely the Rejoso River. The sea water on the coast of Wates District (sample 2) has mid-salinity, even though there is a river that discharges human activities. However, the population is less dense than the Lekok District's population. The salinity on the coast of Semedusari District (sample 3) is the highest because there are no river channels to the coast. Seawater salinity affects the evaporation process until the crystallization process. The higher the salinity of seawater, the salt production process tends to be faster. High salinity also affects the level of NaCl which is an essential component in the quality of salt. The data shows that seawater temperature and water cleanliness (TDS) tended to be directly proportional to seawater salinity. The data also shows that changes in pH are within a normal and safe range.

Filter test

Samples of seawater that have been filtered are also tested with appropriate measuring instruments to see the effect of the filtration process on seawater as a raw material for salt production. Several samples were taken to obtain parameter values to study the effect of using filters in seawater's aging process. There are three samples taken for each season (dry and rainy), namely original seawater, seawater that has passed through the first filter at average speed, referred to as treatment 1, and seawater that has passed through the second filter, referred to as treatment 2. The sample test results are presented in the following table:

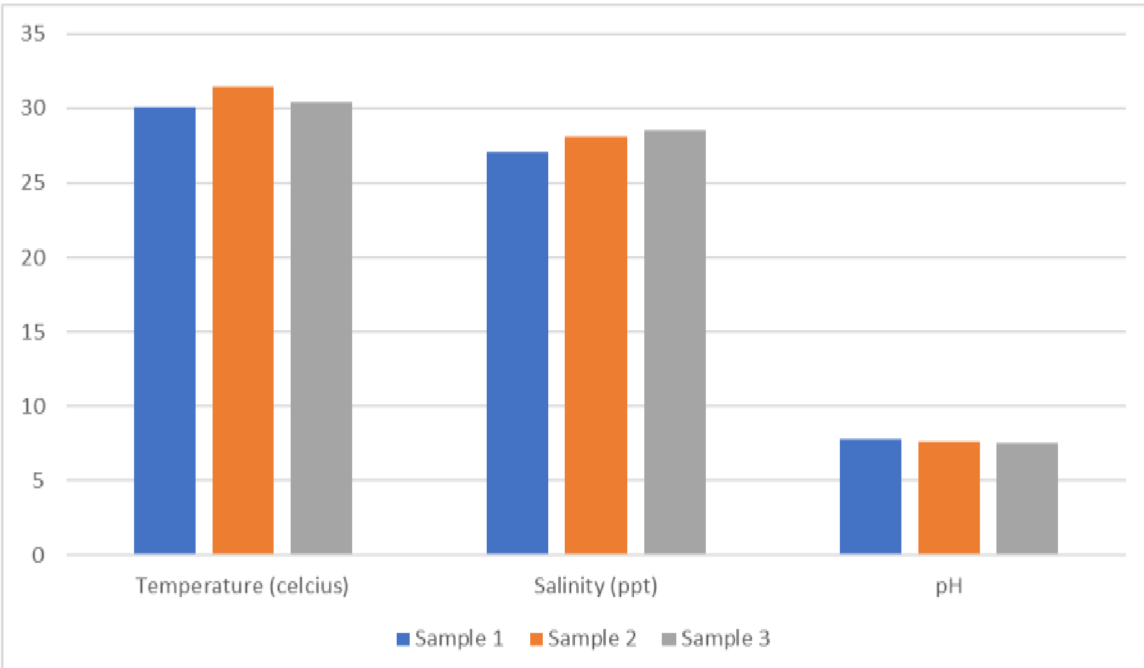

Figure 2 Graph of seawater parameters (temperature, salinity, and pH)

Based on the table, it can be seen that there was no significant change in temperature between the seawater used as a control and those carried out by treatments 1 and 2. The same also applies to the pH value; the first samples as control and samples 2 and 3 did not show a tendency towards neutral nature (salt properties) and are still tolerable. Meanwhile, the salinity value increased after passing through the filter. It means that the material used to make the filter increases salinity. The increased salinity indicates the increased NaCl content in the water due to the filtration system's filtering of Mg and Ca impurities. Filters also affect electrical conductivity (EC), which increases EC. In direct comparison with EC, TDS also shows an increase in value after passing through the filter.

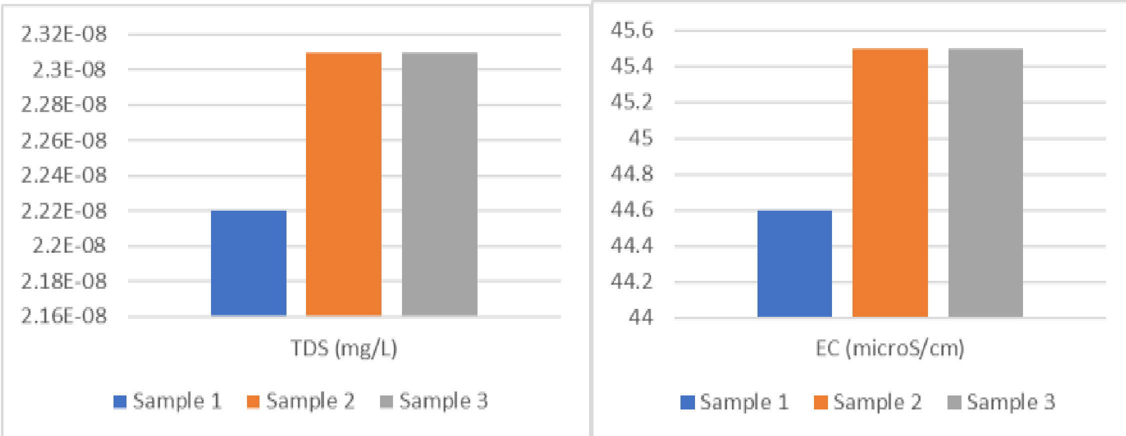

Figure 3 Graph of seawater parameters (TDS and EC)

The evaporation rate in the salt crystallization process is strongly influenced by temperature. Therefore, research on salt production was carried out in two periods, i.e., during the dry and rainy seasons. This choice is because the average temperature inside the crystallization house during the dry season is around 48°C, higher than in traditional salt ponds, which only reach approximately 28.8°C. During the rainy season, the temperature in the crystallization house is around 39°C, while traditional salt ponds cannot produce due to weather constraints.

Salt is produced from bittern, which is produced from brines that have passed through the filter two times and are left for five days. Bittern is placed on the table salt (halite) for the evaporation process so that the crystallization of the salt becomes fast.

The quality of salt can be determined through the content of Ca, NaCl, water content, and Mg in the salt produced. The content of Ca, NaCl, water content, and Mg in salt production is also very dependent on the quality of seawater as a raw material and the location where seawater is taken. The type of pond bottom/salt crystallization table (halite) is also very influential; in this study, a plastic geomembrane bed is used, which is claimed to be the best pond bottom.

Laboratory results for the Ca, NaCl, water content, and Mg from salt samples produced by crystallization house salt with untreated raw materials that received special treatment (filter) taken during the dry season are presented in the following table.

Table 2 The content of salt produced during the dry season

Parameter	Control Value			Salt	
	K1	K2	K3	Sea Water Raw Materials Without Treatment	With Treatment
Calcium	max. 10	max. 10	max. 10	32,94 ± 0.06	30.07 ± 0.08
NaCl	min.87	min.85	min.83	85,46 ± 2.00	87,42 ± 0.90
Water content	max. 7	max. 7	max. 7	7,50 ± 0.10	7,36 ± 0.10

Mg	max. 10	max. 10	max. 10	$6{,}19 \pm 0.08$	$5{,}39 \pm 0.12$
Color	White	White	White	White	White
Smell	no smell	no smell	no smell	no smell	no smell
(Physical) Granules	Congested	Congested	Congested	Congested	Congested

Physically, the form of salt produced from raw seawater without treatment and with treatment does not show any difference. In terms of content, the data in Table 5.3 shows that NaCl is the highest component contained in salt produced during the dry season. The NaCl content of salt with filter treatment was higher than that of salt produced without treatment. Meanwhile, the Ca, Mg, and water content was higher in salt produced without treatment, with successive differences of 2.97 mg/kg, 0.8 mg/kg, and 0.14% of the salt produced with a filter. The following graph is presented to graphically show differences in the quality of salt produced during the dry season.

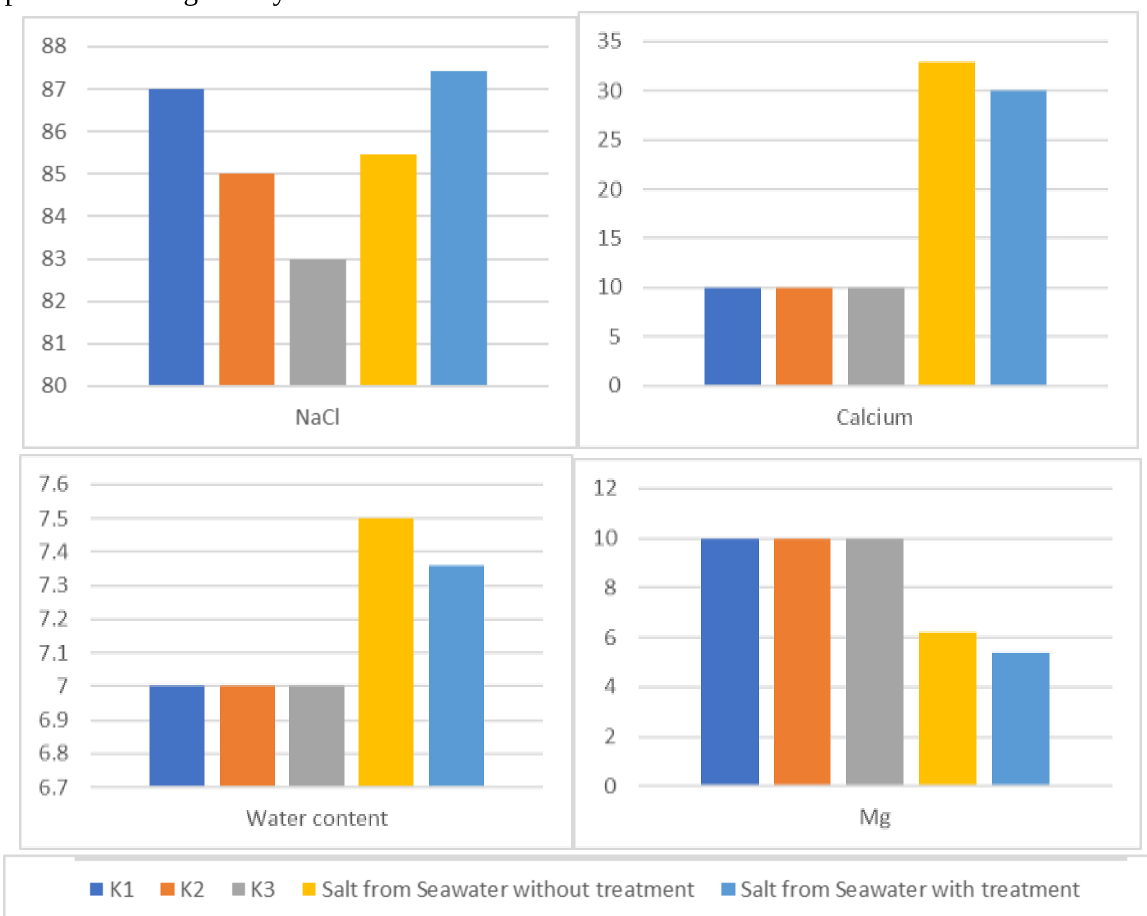

Figure 4 Graph of production salt parameters during the dry season

Based on the Indonesian National Standard (SNI) 4435: 2017, raw material salt for the iodized consumption salt, the quality of salt produced by crystallization houses and grouper cultivation intercropping systems in Lekok District during the dry season with treatment and without treatment is included in the Quality category K1 and K2. These results indicate that salt production using crystallization houses and grouper cultivation intercropping systems in Lekok District can produce salt quality that meets the Indonesian National Standard (SNI) standards.

The salt's water content can affect the salt's NaCl content. An increase in the salt's water content affects the salt's NaCl content; the higher the water content in the salt, the concentration of other compounds, including the NaCl compound, will decrease. However, the water content in the crystallization house salt and the grouper culture intercropping system in Lekok District analyzed in this study is still tolerable, considering the water content in salt according to SNI 4435: 2017 is a maximum of 7%. Water content that is more than 7% can be managed by increasing the salt draining time.

The NaCl level in the salt in this study was also strongly influenced by the presence of impurities such as Mg and Ca. Mg^{2+} compound and Ca^{2+}will form $MgCO_3$ and $CaCO_3$ compounds where all the compounds formed will precipitate. From the salt data produced by the Crystallization house and the grouper culture intercropping system in Lekok District, Mg and Ca impurities can still be tolerated considering that the NaCl content is high enough for the salt can be categorized as K1 quality salt.

a b

Figure 5. a Salt produced during the dry season from seawater without treatment 6. b Salt from seawater with treatment

In addition to the quality of the salt, the level of productivity of salt using crystallization houses and grouper cultivation intercropping systems in the Lekok District has also increased. It only takes five days from the initial process until salt is produced during the dry season. The process takes little time due to the presence of a filter which accelerates the process of increasing water salinity and reducing impurities. Seventy-five liters of raw seawater placed on halite measuring 3×2 meters produced approximately 10 kg of salt.

Furthermore, samples of salt produced during the rainy season were also taken; laboratory results for the content of Ca, NaCl, water content, and Mg are presented in the following table.

Table 3 The content of salt produced during the rainy season

Parameter	Salt	
	Sea Water Raw Materials Without Treatment	With Treatment
NaCl	$76{,}64 + 0{,}40$	$78.31 + 0.10$
Water content	$6{,}32 + 0{,}15$	$6.18 + 0.1$
Color	White	White
Smell	no smell	no smell
(Physical) Granules	Congested	Congested

Like during the dry season, salt produced in the rainy season from raw seawater without treatment and with treatment does not show any difference physically. In terms of content, the data in Table 5.6 shows that NaCl is the highest component contained in salt produced during the rainy season. The NaCl content of salt with filter treatment was higher than that of salt produced without treatment. Meanwhile, water content was higher in salt produced without treatment, with successive differences of 0.14% from salt produced with a filter.

The water, Ca, and Mg content in salt produced in the rainy season have higher levels than salt produced in the dry season, considering that the temperature in the crystallization house also decreases. In addition, the content of seawater, the raw material for salt, also changes during the rainy season. Even so, the quality of the salt produced by the crystallization house and the intercropping system for grouper cultivation in the Lekok District is increasing. Based on the Indonesian National Standard (SNI) 4435:2017, the quality of salt is under K3.

The level of salt productivity using a crystallization house and grouper cultivation intercropping system in the Lekok District during the rainy season has also increased drastically. Previously, the community could not even produce salt during the rainy season due to the weather. Meanwhile, using a crystallization house and filters in this research model, the salt production process can continue even though it takes longer. It takes about 45-50 days from the initial process until salt is produced in the rainy season.

Cost Benefit Analysis for salt production.

- Benefit Value Cost

In order to carry out intercropping salt production with crystallization houses and grouper cultivation, business people need to collect information in advance regarding the fixed costs and variable costs required to run the business. Business investment capital can adjust the size of the pond to be made and the human resources available to process it. Investment capital from intercropping salt production with crystallization houses and grouper cultivation in general with an added size of 6 m2 with one crystallization house is presented in the table below.

Table 4 Table of cost benefits of salt production

No	Tool's name	Unit Price (IDR)	Amount	Total Cost (IDR)
Crystallization House				
1.	Bamboo	15,000	4	60,000
2.	White UV plastic	16,000	4	64,000
3.	Black UV Plastic	14,000	3	42,000
4.	Spike	30,000	1	30,000
5.	Rope	25,000	1	25,000
Piping				
6.	Pipe	75,000	1	75,000

7.	Sea water pump	250,000	1	250,000
8.	Bucket	50,000	1	50,000
9.	Pipe glue	12,000	1	12,000
10.	Faucet	45,000	1	45,000
11.	Tape	10,000	1	10,000
Filter				
13.	Spons	10,000	2	20,000
14.	Zeolite	15,000	4	60,000
15.	Ginger Coral	10,000	5	50,000
16.	Coconut Charcoal	15,000	5	75,000
17.	Shell Charcoal	10,000	5	50
Total				918,000

The table above shows that the required investment capital is IDR 918,000 for salt production.

- Fixed cost

Fixed Costs are costs that do not change as long as the business runs, whether during production or not. These costs will still be incurred even if not carrying out production activities. The fixed costs incurred in the salt production business using a crystallization house with a filter system can be seen in the table below.

Table 5 Fixed cost of crystallization house salt production by intercropping grouper cultivation

No.	Fixed cost (Per Harvest Period)	The amount of costs (IDR)
1.	Water pump maintenance	50,000
2.	Electricity	450,000
Total		500,000

The table above shows that the fixed or maintenance costs in a crystallization house salt production with a filter system within one year are around IDR 500,000.

- Marketing / Sales

The marketing areas for salt and grouper products are collectors or individuals, restaurants/hotels, and factories around the coast. In product marketing, only use social media and placards in front of the ponds so that marketing does not require high costs. As the model made, 180 liters of bittern with a salinity of 140 ppt can produce as much as 20 kg of salt or 6 kg per liter. The salt produced is K1 salt; per kg can be sold at IDR 11,000. Salt sales per harvest are usually valued at IDR 220,000

- Calculation of Cost Benefit Analysis

Table 6. ROI calculation

Tangible Benefits	
Sales of crops (9 periods/year)	1,980,000
The total cost of year 1	1,418,000
Payback Period (PP)	0.716 years
Year 1 progress	1,980,000
Remaining investment year 2	0
NPV (Net present value)	259,966
Total Cost 2 years	1,918,000
Total Benefits 2 years	3,960,000
ROI (Return on Investment)	106.46%

The investment cost of producing salt with a filter system will be covered within 0.716 years or 8.59 months. The total net profit from the salt production business with a filter system in 2 years is IDR 3,960,000, and the investment cost closing rate is 106.46% per year. Based on the results of CBA analysis on salt production in this study, salt production with a filter system is feasible to support the community's economy.

Cost-benefit Environmental Analysis

The type of loss calculated based on the impact caused by the production of crystallization house salt by intercropping grouper cultivation is as follows.

- Calculation of the Cost of Losses for the Community's Economic Losses

Table 7 Societal loss costs

No	Description	Information
1.	Number of households	123
2.	The price of production salt before any research(P_o)	5,000
3.	Price of production salt after research(P_1)	11,000
4.	Number of fish consumed before the study(Q_o)	55 kgs
5.	The number of fish consumed after the research(Q_1)	60 kgs
6.	Impact severity	1% (applying CAS)
7.	Sk_o	$0,5 \times RT \times P_o \times Q_o$
		$0,5 \times 123 \times 5,000 \times 55 = 16,912,500$
8	SK_1	$0,5 \times RT \times P_1 \times Q_1$

		$0,5 \times 123 \times 11,000 \times 60 = 40,590,000$
9.	Change SK	$SK_o - SK_1$
		23,677,500
10	Loss value	Impact severity $\times$ change SK
		236,775

The community loses value with the assumption that one year is equal to Community loss = 236,775 x 12 months = IDR 2,841,300

- Calculation of Loss Costs and Ecological/Environmental Recovery

1. *Water System Function Recovery Costs*

Table 8 Water System Function Recovery Costs

The national cost of water system function recovery	40,500,000/ha
Pond area	$6m^2$
Total	$\frac{6}{10000} \times 40,500,000 \times 1 = 24,300,-$

2. *Water Arrangement Costs*

Table 9 Water Arrangement Costs

The national cost of water arrangement	22,810,000/ha
Pond area	$6m^2$
Total	$\frac{6}{10000} \times 22,800,000 = 13,686,-$

3. *Land Formation Costs*

Table 10 Land Formation Costs

The national cost of land formation	500,000/ha
Pond area	$6m^2$
Total	$\frac{6}{10000} \times 500,000 = 300$

4. *Nutrient Loss Costs*

Table 11 Nutrient Loss Costs

The national cost of nutrient loss	4,610,000
Pond area	$6m^2$

Total	$\frac{6}{10000} \times 4{,}610{,}000 = 2{,}766$

5. *Biodiversity Recovery Costs*

Table 12 Biodiversity Restoration Costs

The national cost of biodiversity restoration	2,700,000
Pond area	$6m^2$
Total	$\frac{6}{10000} \times 2{,}700{,}000 = 1{,}620$

6. *Genetic Recovery Costs*

Table 13 Genetic Recovery Costs

The national cost of genetic recovery	410,000
Pond area	$6\ m^2$
Total	$\frac{6}{10000} \times 410{,}000 = 246$

7. *Carbon Release Costs*

Table 14 Carbon Release Costs

The national cost of carbon release	32,310,000
Pond area	$6\ m^2$
Total	$\frac{6}{10000} \times 32.310{,}000 = 19{,}386$

Based on the calculated environmental profit and loss analysis simulation results, the total environmental loss is IDR 62,304.

Comparison of results of CBA and CBEA of domestic salt production activities

Table 15 Total net benefits

No	Value Type	Value Estimation
1.	Total Benefit Value (CBA) (Rp/year)	10,320,745
2.	Total Value of Losses (CBEA) (Rp/year)	62,304
	Total net benefit value (Rp/year)	10,258,441

It found that the benefits from this innovation were good enough to support the community's economy. In addition, this advantage is also offset by the results of the Cost-Benefit Environmental Analysis, which show that this innovation results in minimal environmental losses.

References

[1] M. Silooy, "Analisis Faktor-Faktor Yang Mempengaruhi Tingkat Di Desa Seilale Kecamatan Nusaniwe," *Cita Ekon. J. Ekon.*, vol. XI, no. 1, 2017.

[2] A. F. Aminuloh, L. Supenti, and K. Kamsiah, "Analisis Permasalahan Usaha Garam Rakyat di Kecamatan Kwanyar Kabupaten Bangkalan," *J. Penyul. Perikan. dan Kelaut.*, vol. 13, no. 1, pp. 93–105, 2019, doi: 10.33378/jppik.v13i1.116.

[3] S. P. K. Soedarmo, *Pelestarian Hutan Mangrove dan Peran Serta Masyarakat Pesisir*. Semarang: Undip Press, 2018. [Online]. Available: http://eprints.undip.ac.id/77816/1/Pelestarian_Hutan_Mangrove_dan_Peran_Serta_Masyarakat_Pesisir.pdf

[4] H. S. Suwoyo, "Kajian Kualitas Air pada Budidaya Kerapu Macan (Epinephelus fuscoguttatus) Sistem Tumpang Sari di Areal Mangrove," *J. Berk. Perikan. Terubuk*, vol. 39, no. 2, pp. 25–40, 2011.

[5] C. P. Paruntu, A. B. Windarto, and M. Mamesah, "Mangrove dan Pengembangan Silvofishery di Wilayah Pesisir Desa Arakan Kecamatan Tatapaan Kabupaten Minahasa Selatan Sebagai Iptek Bagi Masyarakat," *J. LPPM Bid. Sains dan Teknol.*, vol. 3, no. 2, pp. 1–25, 2016, [Online]. Available: https://media.neliti.com/media/publications/109014-ID-mangrove-dan-pengembangan-silvofishery-d.pdf

[6] A. Waluyo, "Secara Terpadu Yang Berbasis Masyarakat (Studi Kasus Pulau Raas Kabupaten Sumenep Madura)," vol. 7, no. 2, pp. 75–85, 2014.

[7] Anak Agung Istri Ari Atu Dewi, "Model Pengelolaan Wilayah Pesisir Berbasis Masyarakat," *J. Penelit. Huk.*, vol. 18, no. 2, pp. 163–182, 2018.

[8] R. Bramawanto, S. L. Sagala, I. R. Suhelmi, and H. Triwibowo, *Kajian Pengelolaan Tambak Garam Rakyat Terpadu*. Jakarta: Pusat Penelitian dan Pengembangan Sumber Daya Laut dan Pesisir, 2015.

[9] D. Amami and I. Ihsannudin, "Efisiensi Faktor-Faktor Produksi Garam Rakyat," *Media Trend*, vol. 11, no. 2, p. 166, 2016, doi: 10.21107/mediatrend.v11i2.1600.

[10] C. Anam, "Tekhnologi Rumah Prisma Untuk Produksi Garam," *Vol. I, Nomer 2, Desember 2018*, vol. I, pp. 63–74, 2018.