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Assessing the Sustainability of Smallholder Salt Enterprises on Madura Island, Indonesia: A Comparison of Four Salt Production Methods (Technologies)

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ABSTRACT

This study compares the quality characteristics of salt produced using four different production methods on Madura Island, namely traditional production technology, tunnel technology, geomembrane technology, and land-integrated production technology. The research employed a descriptive quantitative approach, supported by systematic field observations and laboratory-based measurements to ensure reliable and objective results. Salt samples were collected from nine production sites located across three regencies on Madura Island, representing variations in production scale, environmental conditions, and technological adoption. The analysis focused on three key quality indicators—NaCl content, salt whiteness, and water content—which were assessed in accordance with standards established by Indonesia's Ministry of Marine Affairs and Fisheries and SNI 8207. Salt quality testing was conducted using a Saltdec

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M102 salt detector to maintain consistency and accuracy throughout the evaluation process. The findings indicate that salt produced using tunnel technology, geomembrane technology, and land-integrated production technology generally demonstrates superior quality compared to traditional methods. These technologies tend to yield higher NaCl concentrations, lower moisture levels, and better salt cleanliness, making them more suitable for meeting industrial and consumption standards. Nevertheless, each production method presents distinct advantages and limitations related to investment costs, labor intensity, technological complexity, and environmental suitability. Traditional salt production, for instance, remains widely practiced due to its simplicity, low capital requirements, and adaptability to local conditions, despite its relatively lower salt quality. Based on these findings, future policy efforts by the Ministry of Marine Affairs and Fisheries should prioritize the promotion of improved production technologies, including the corporatization of salt lands through land integration, as a strategy to enhance productivity, strengthen competitiveness, and improve the overall welfare of salt farmers.

Keywords: Sustainability; Production Technology; Smallholder Salt Enterprises

1. Introduction

Salt serves as a raw material and an auxiliary material in the chemical industry, accounting for about 60 percent of the world's total salt production^[1]. In Indonesia, rapid industrial growth drives the demand for industrial salt, which represents 82.28 percent of the country's total salt needs^[2,3].

Most seawater evaporation salt ponds worldwide produce low-quality salt^[4]. Evaporated seawater salt often appears impure and dirty, and contains harmful compounds that reduce its suitability for the chemical industry, food processing, and other industrial uses^[5]. Advanced salt purification technology, however, removes these impurities from salt crystals with minimal salt loss during processing^[6].

Favorable natural conditions—100 percent solar radiation intensity, low humidity, limited rainfall, and a long dry season—contribute to seawater with high salinity that remains unmixed with freshwater from estuaries^[7-9]. Fauziyah et al.^[8] stated that traditional salt production carried out directly on the ground requires 12–15 days, produces low-quality salt, and results in a cloudy appearance^[10]. By contrast, salt production using geomembrane technology, which lines the crystallization ponds with waterproof plastic to prevent contact between salt and soil, produces cleaner results^[4]. The following section presents a comparative calculation of salt characteristics from different production methods on Madura Island, Indonesia, focusing on NaCl content, whiteness, and water content.

2. Materials and Methods

This research took place from January to April 2024 in nine salt-producing villages on Madura Island. The villages were spread across three regencies: Sampang, Pamekasan, and Sumenep. These regencies were chosen because they have the highest levels of production, land productivity, and salt-producing areas on the island. Known as Indonesia's "Salt Island," Madura contributes nearly 29 percent of the national salt demand (Indonesia's Ministry of Maritime Affairs and Fisheries and Central Bureau of Statistics of Indonesia, 2023). The research sites included Ragung and Marparan Villages in Sampang Regency; Padelegan Village, East Pademawu Village, Bunder Village, and Lembung Village in Pamekasan Regency; and Sentol Daya Village and Karanganyar Village in Sumenep Regency (see **Figure 1**). The team also conducted fieldwork in Badduriah, Pademawu District, Pamekasan Regency. The research team interviewed salt farmers about their production technologies and collected salt samples for further analysis. The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Universitas Sembilanbelas November Kolaka with permit number 12/UN.56D.01/PN.03.00/2024 on 10th January 2024. Informed consent was obtained from all subjects involved in the interview. The artisanal salt analyzed came from the 2023 and 2024 production seasons. Researchers then tested the NaCl content, water content, and whiteness of the salt crystals from the nine locations using a Saltdec M102 salt detector (see **Figure 2**).



Figure 1. Nine salt sampling locations on Madura Island.

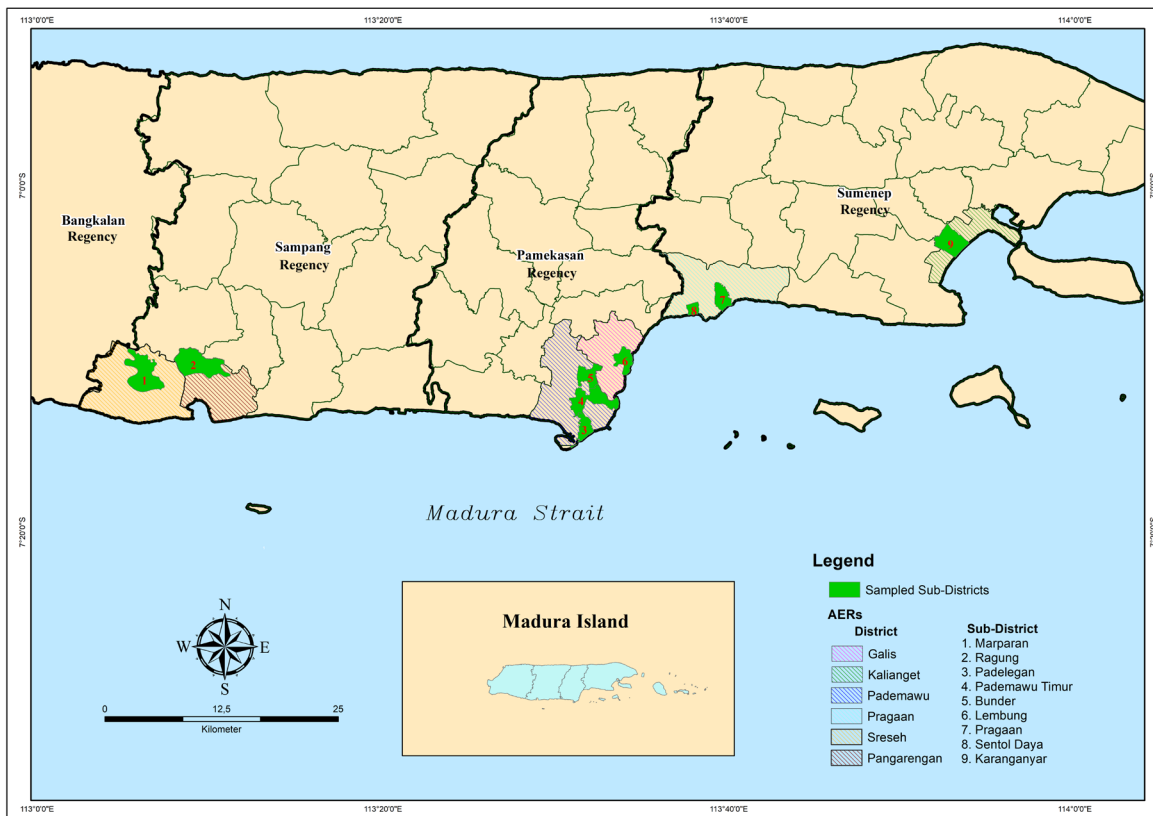


Figure 2. Tools and materials for testing the characteristics and quality of salt production on Madura Island.

3. Results and Discussion

3.1. The Comparison of Production Methods: Traditional and Geomembrane Technologies

3.1.1. Traditional Technology

Salt production in Indonesia largely relies on traditional methods. As a result, the quality of domestically produced

salt often fails to meet health standards, generally falling below Grade II according to SNI/SII No. 140-76 specifications [11]. Hidayat et al. [12] reported similar findings, explaining that salt production methods in Indonesia still depend heavily on conventional systems and natural conditions, such as weather, climate, and sunlight intensity. Wu et al. [13] emphasized that the traditional salt production method, also known as evaporation, strongly influences seawater salinity. Several factors affect salinity levels, as follows.

- a. Evaporation: A higher seawater evaporation rate increases salinity levels. Conversely, when evaporation is low, salinity decreases.
- b. Rainfall: Regions with high rainfall tend to have lower salinity levels, while areas with low rainfall show higher salinity.
- c. Rivers: When many rivers flow into the sea, freshwater input lowers salinity. In contrast, fewer rivers contribute less freshwater, which increases salinity.

In the traditional method, salt farmers use soil as the base medium. During harvesting, soil particles often stick to the salt surface, affecting its color. Soil serves multiple functions: it retains water, supports evaporation, and provides a crystallization surface that receives direct sunlight. Banicod et al. ^[14] explained that the use of soil in traditional production affects not only the quantity but also the quality of salt, since soil introduces impurities into the crystals ^[14]. These impurities are closely related to the soil's physical condition, particularly its texture. Soil texture plays a critical role in seawater salt production. Salt ponds require soil with low permeability that resists cracking during periods of low humidity ^[8]. Based on its visual characteristics, salt produced through the traditional method generally falls into Quality III salt, as specified by the Standard Regulations of the Directorate General of Foreign Trade ^[7].

At the research site, the community practices two traditional methods: the Portuguese production method and the Madurese production method. The primary difference between the two lies in the duration of the crystallization process before the salt forms grains ready for harvest. The Madurese method produces salt more quickly, while the Portuguese method requires a longer crystallization period. Farmers must age the water in the crystallization pond for about 30 days before it reaches harvesting standards. Because of this difference, salt produced using the Madurese method is younger and of lower quality compared to salt from the Portuguese method. This lower quality directly affects the selling price. Salt produced traditionally with the Portuguese method commands a higher market price than salt produced using the Madurese method.

Despite the presence of both methods, production practices across the study area remain fairly consistent. In general, salt farmers in Sampang, Pamekasan, and Sumanep Regencies continue to rely on the Portuguese method.

Interviews revealed that PT Garam first introduced this method, which the local community later adopted. Farmers initially practiced a technique of layering salt over salt, but over time, they recognized its inefficiency. As a result, they shifted toward the production techniques modeled by PT Garam.

3.1.2. Geomembrane Production Technology

Since 2011, Indonesia's Ministry of Maritime Affairs and Fisheries, through its extension workers, has promoted an innovation in salt production: the use of geomembrane flooring. This technology plays a valuable role in boosting national salt production. Its primary purpose is to improve the quality and quantity of salt. Instead of producing salt directly on the soil, farmers use a geomembrane tarpaulin ^[14]. This layer minimizes impurities in the salt and reduces brine leakage because soil absorption becomes negligible or even nonexistent.

Geomembrane consists of sheets made from high-density polyethylene (HDPE) with high and uniform impermeability, functioning as a waterproof liner. In addition to its impermeability, geomembrane offers resistance to ultraviolet radiation and hazardous chemicals. This property makes it effective in preventing seawater contamination from waste that sometimes collects in ponds, which may contain not only dirty water but also hazardous substances ^[15].

Salt produced with geomembrane technology appears clear white and falls under Production Quality I classification. Its quality—in color and grain size—surpasses salt produced traditionally on the same land. The improvement occurs because the geomembrane prevents direct contact between brine and soil, eliminating soil contamination on the crystallization surface during the harvesting process ^[16,17].

At the research site, interviews with salt farmers showed that geomembrane production technology produced higher yields, cleaner and whiter salt, and better prices. Farmers also emphasized that this technology crystallizes salt much faster than traditional methods. These findings align with Arwiyah et al. ^[1], who reported that geomembrane technology not only increases salt production compared to traditional methods but also shortens the production process ^[1,4,7].

Salt farmers at the research site also confirmed that production with geomembrane technology generates higher prices than traditional methods. This directly increases their acceptance level and overall income. Although the initial investment is relatively high, the revenue earned through geomembrane production surpasses that of traditional land-based methods. These findings support Prihantini et al. [4]

and Fauziyah et al. [9], who concluded that geomembrane technology outperforms traditional methods. While the production costs of geomembrane technology are higher, the salt produced remains superior in quality and quantity compared to salt made using traditional salt tables. The differences between the Portuguese production method and geomembrane (geomembrane) technology appear in **Table 1**.

Table 1. The comparison of harvesting methods for two salt production technologies on Madura Island in 2024.

Description	Salt Harvesting in Production Technologies	
	Traditional Production Techniques	Geomembrane Production Technology
Salt Table	Crystallization made from unharvested salt from the first month	HDPE polymer base (geomembrane)
Embankment Construction	Mounded soil reinforced with white bricks	Mounded soil
Harvesting	<ul style="list-style-type: none"> •Can be done 1 month after the start of the season •Requires a chopper to break and separate salt from the bed 	<ul style="list-style-type: none"> •Can be done at the start of the season •No chopper required because the salt separates easily from the bed
Salt Quality	<ul style="list-style-type: none"> •Production Quality I (regular harvest) •Production Quality III (salt bed collected at the end of the season) 	Production Quality I (all harvests)
Harvest Period	<ul style="list-style-type: none"> •Initial stage: 30 days •Second stage: 15 days •Third stage: 8–10 days 	<ul style="list-style-type: none"> •Initial stage: 25 days •Second stage: 9–10 days •Third stage: 7–9 days

Source: Field interview results (2024).

3.2. The Comparison of Characteristics and Production Quality

This section explains the comparison of salt characteristics and quality across several research locations. The first step involved collecting salt samples from three regencies on Madura Island: Sampang, Pamekasan, and Sumenep. In Sampang Regency, samples came from Marparan Village (Sresch District) and Ragung Village (Pangarengan District). In Pamekasan Regency, samples were collected from Polagan Village (Galis District) and Bunder Village (Pademawu District). In Sumenep Regency, samples were obtained from Sentol Daya Village (Peragaan District).

After collecting samples, the researchers conducted testing at one of the people’s salt business groups in Sentol Daya Village, which also manages a salt cooperative. Using a detector, the team identified the salt quality based on Production Quality categories I, II, or III. The Maritime Affairs and Fisheries Office donated this device as part of the salt cooperative’s inventory in Sentol Daya Village.

The Saltdec M102 consists of two devices: one for testing NaCl content and another for measuring water content, as shown in **Figure 2**.

Furthermore, the researchers ground the salt samples using a mortar and pestle until the texture became very fine. After grinding, they placed the salt into two devices labeled P1 and P2. Device P1 tested the NaCl content, while device P2 measured the moisture content and whiteness of the salt. According to regulations issued by Indonesia’s Ministry of Maritime Affairs and Fisheries and the Indonesian National Standard (SNI) 8207:2016, salt can be classified based on the criteria shown in **Table 2**.

All salt produced by local communities and sold to cooperatives must undergo NaCl and moisture testing using the detector to determine whether the quality falls into Production Quality I, II, or III. The comparative analysis of salt characteristics conducted at different research sites showed significant variation. The results of NaCl and moisture content tests from several research locations are presented in **Table 3** and **Appendix A**.

Table 2. Salt quality categories in Indonesia.

No.	Salt Quality Classification	NaCl Content (%)
1.	Production Quality I	NaCl > 97.1
2.	Production Quality II	94.4 < NaCl < 97
3.	Production Quality III	NaCl < 94

Quality Requirements for Industrial Salt for Various Foods According to SNI 8207:2016

No.	Unit Test Criteria	Unit	Requirement
1.	Sodium Chloride (NaCl), adbk	Mass Fraction, %	Minimum 97%
2.	Moisture Content (H ₂ O)	Mass Fraction, %	Maximum 5%

Source: Indonesia’s Ministry of Marine Affairs and Fisheries (Indonesia’s Ministry of Maritime Affairs and Fisheries, 2006) in Arwiyah et al. [1]; SNI 8207:2016 in Gozan et al. [11].

Table 3. The comparison of salt production quality characteristics at several research locations.

No.	The Origin of Salt Samples & Production Technology	NaCl Content (%)	Water Content (%)	Whiteness Level (%)	Salt Classification
1.	Polagan Village (Pamekasan)—Geomembrane	93.36	5.67	80.11	Production Quality III
2.	Padelegan Village (Pamekasan)—Integrated Land	98.51	2.54	80.31	Production Quality I
3.	Lembung Village (Pamekasan)—Traditional (Soil)	93.12	4.22	80.73	Production Quality III
4.	Marparan Village (Sampang)—Traditional (Soil)	89.91	4.86	73.31	Production Quality III
5.	Ragung Village (Sampang)—Geomembrane	98.24	3.25	74.95	Production Quality I
6.	Karanganyar Village (Sumenep)—Geomembrane	95.02	5.99	73.15	Production Quality II
7.	Sentol Daya Village (Sumenep)—Tunnel	98.36	2.72	77.58	Production Quality I
8.	Sentol Daya Village (Sumenep)—Geomembrane	97.15	3.10	80.46	Production Quality I
9.	Sentol Daya Village (Sumenep)—Traditional (Soil)	93.71	5.73	77.61	Production Quality III

Source: SaltDec test results (2024).

The detector analysis revealed that salt produced using geomembrane technology in three research sites—Ragung Village (Sampang Regency), Karanganyar Village (Sumenep Regency), and Sentol Daya Village (Sumenep Regency)—met the Production Quality I. However, one geomembrane-based salt sample from Polagan Village (Pamekasan Regency) fell into the Production Quality III.

Salt samples produced using traditional methods (soil-based) at three research locations all fell into the Production Quality III: Bunder Village (Pamekasan Regency), Marparan Village (Sampang Regency), and Sentol Daya Village (Sumenep Regency). The analysis using a detector provided by Indonesia’s Ministry of Marine Affairs and Fisheries confirmed that the quality of salt produced with geomembrane technology was higher than that of salt produced using traditional soil-based methods. The distribution of sampling points across Madura Island ensured that salt samples were selected randomly.

In addition, salt produced through integrated land and tunnel production methods consistently fell into the Production Quality I category. This finding indicates that

these two production techniques yield excellent results. Specifically, the salt produced has a high NaCl content, low moisture content, and a relatively high whiteness level. Both methods clearly demonstrate advantages in producing Production Quality I salt. However, their main challenges lie in the high investment costs and the limited suitability of available land for construction. Therefore, stakeholders need to explore solutions and strategies to support the integration of these advanced production technologies with integrated land and tunnel housing systems.

3.3. The Comparison of Salt Business Profits and Production between Traditional Methods and Geomembrane Technology

This section compares the average production, salt field productivity, salt prices, and income structure of salt businesses between the treatment group (farmers who adopted geomembrane technology) and the control group (farmers who did not adopt it). Respondents who are salt farmers produce granulated salt that undergoes

post-harvest sun-drying to reduce moisture content. The average productivity of all respondent salt farmers is 93.29 t/ha. This calculation includes total salt production across all quality categories: Production Qualities I, II, and III. Farmers using geomembrane technology demonstrate higher productivity than those relying on traditional methods. On average, geomembrane farmers achieve 99.28 t/ha, while traditional farmers reach 88.92 t/ha.

Among adopters, productivity has already surpassed the national average salt field productivity for 2023, which was 96.37 t/ha (Indonesia’s Ministry of Maritime Affairs and Fisheries, 2024). Meanwhile, productivity among non-adopters remains below this benchmark. **Table 4** presents data on average production, productivity, and salt prices received by respondent salt farmers during the 2023 production season.

Table 4. Average production, productivity, and price of salt from geomembrane and traditional farmers on Madura Island in 2024.

Description	Geomembrane		Traditional	
Land Area (ha)	1.0008		1.1000	
Production	Value (ton)	Percentage (%)	Value (ton)	Percentage (%)
Production Quality I	88.01	93.25%	-	0.00%
Production Quality II	5.36	6.75%	78.98	80.75%
Production Quality III	0.00	0.00%	18.83	19.25%
Total (tons)	94.37		97.81	
Productivity (t/ha)	99.28		88.92	
	Selling Price (IDR/ton)			
Production Quality I	2,375,800		-	
Production Quality II	2,150,250		2,030,125	
Production Quality III	-		1,050,000	
Average Price (IDR/ton)	2,063,025		1,540,062	

Source: Processed primary data (2024).

The price of salt that respondents receive depends on the quality of the salt they produce. In principle, Indonesia’s Ministry of Trade regulates the price received by salt farmers. Farmers who use geomembrane technology earn higher prices than traditional farmers because most of their output qualifies as Production Quality I salt, while traditional farmers typically produce salt of no more than Production Quality II. Traditional farmers rarely succeed in producing Production Quality I salt. The 2023 salt production season proved highly favorable for salt farmers. Interviews revealed that they received considerably better prices compared to previous years. Geomembrane farmers earned an average price of IDR 2,063,025 per ton, while traditional farmers earned IDR 1,540,062 per ton. At the beginning of the production season, the price of Production Quality I salt even reached IDR 5,500,000 per ton in Pamekasan Regency and IDR 3,300,000 per ton in Sumenep Regency. These high prices significantly boosted farmers’ incomes and improved their overall well-being. For example, several members of the People’s Salt Business Group (Indonesian: Kelompok Usaha Garam Rakyat [KUGAR])

could not attend interviews because nearly all of them were performing the Umrah pilgrimage to the Holy Land. This situation highlights how strong salt prices were during the 2023 production season, far exceeding the benchmark set by the Directorate General of Foreign Trade.

In some cases, the prices that salt farmers receive do not align with government-set prices. Numerous studies have confirmed that the actual prices fall short of the expected values^[18]. Prihantini et al. and Farrokhi et al.^[6,7] reported that although the government has issued a reference price for salt, market prices remain significantly below this benchmark.

The next section compares the income structure of smallholder salt enterprises managed by adopted and non-adopted salt farmers. As shown in **Table 5**, the income structure indicates that geomembrane farmers earn significantly more than traditional farmers. On average, geomembrane salt farmers earn IDR 120,318,428 per hectare, while traditional farmers earn only IDR 80,110,772 per hectare. The gap in income reflects not only higher productivity but also the premium price that geomembrane farmers receive

compared to traditional salt farmers. **Table 5** presents detailed information on the revenue and cost analysis of smallholder salt ponds using geomembrane and traditional methods on Madura Island.

Table 5. The analysis of revenue and costs of salt pond business per hectare for geomembrane and traditional farmers on Madura Island in 2024.

Description	Geomembrane		Traditional	
	Value	%	Value	%
Revenue (IDR/ha)	120,318,428	100	80,110,772	100
Operating Costs (IDR/ha)	28,887,515	100	28,958,490	100
1. Land Rent	4,302,655	14.89	6,124,750	21.15
2. Equipment	3,759,240	13.01	801,770	2.77
2.1. Depreciation	3,500,550		715,885	
2.2. Rent	258,690		85,885	
3. Labor Costs	18,317,650	63.41	21,737,580	75.06
4. Sack Costs	2,292,750	7.94	2,498,815	8.63
5. Others	215,220	0.75	44,575	0.15
Profit (IDR/ha)	91,430,913	75.99	51,152,282	63.85
R/C	4.17		2.77	

Source: Processed primary data (2024).

In terms of cost structure, geomembrane salt farmers incur higher average operating and total costs than traditional salt farmers. Geomembrane salt farmers spend an average of IDR 28,887,515 per hectare, with labor costs making up the largest share at 63.41%. Traditional salt farmers, on the other hand, spend an average of IDR 28,958,490 per hectare, with labor costs accounting for the highest share at 75.06%. The average income of geomembrane salt farmers is significantly higher than that of traditional salt farmers. Higher production volumes and substantial price differences contribute to this higher profitability. During the 2023 production season, geomembrane salt farmers earned an average of IDR 91,430,913 per hectare, while traditional salt farmers earned IDR 51,152,282 per hectare.

An analysis of the revenue and cost structure of smallholder salt businesses shows that the R/C ratio is greater than 1 ($R/C > 1.00$), indicating that geomembrane and traditional methods remain viable. However, geomembrane technology delivers a higher R/C value than traditional methods. The R/C ratio for smallholder salt businesses using geomembrane technology reached 4.17. This means that for every IDR 1 million spent, farmers earned

IDR 4.17 million in revenue. In contrast, traditional salt farming produced an R/C ratio of 2.77, meaning that each additional IDR 1 million in costs generated IDR 2.77 million in revenue. These values differ from previous production seasons and may change in the future. One of the key factors driving this variation is the fluctuation in salt prices [19]. In the 2023 harvest season, salt prices soared above the rates set by Indonesia’s Ministry of Trade, significantly boosting farmer profits.

3.4. Introducing Two New Production Technologies for the Salt Business

3.4.1. Tunnel Technology Innovation

Tunnel represents a new breakthrough in salt production (see **Figure 3**). Farmers who adopt tunnels no longer depend on the weather. Traditionally, during the rainy season, most salt farmers stop producing salt because crystallization relies heavily on sunlight, which becomes ineffective in rain. Tunnels address this challenge by enabling production even in the rainy season.



Figure 3. Tunnel is the newest production method in Sentol Daya Village, Peragaan District, Sumenep Regency.

Tunnels are built using bamboo frames, with geothermal plastic covering the roof and a geomembrane lining the base. The geomembrane helps stabilize heat from sunlight, producing higher-quality salt. Inside the tunnel, solar heat is trapped and retained at night, which accelerates the crystallization process and shortens the harvest period [20–22].

The modernization of smallholder salt businesses continues with the development of innovative production technologies in salt ponds. Beyond the widely used geomembrane technology, tunnels now serve as an alternative solution. Tunnels generally come in two types: tunnel-shaped and prism-shaped [23–26].

PT Garam Persero first introduced prism-shaped tunnels in 2016. Among smallholder salt farmers, the first use of tunnel technology was pioneered by Jauhari from Sentol Daya, in collaboration with the Maritime Affairs and Fisheries Office of Sumenep Regency, who implemented a tunnel-shaped model. These tunnels use bamboo frames with clear geothermal plastic as a cover and a geomembrane

lining the pond base. The main advantage of tunnel technology lies in its independence from weather conditions, allowing consistent production of Production Quality I salt. Even during the rainy season, a tunnel covering a crystallization area of 159 m² can produce up to 19 t of salt.

Based on **Table 6**, the investment analysis of a salt production business using tunnel technology shows several essential equipment components. This investment represents the initial capital required for salt farmers to operate their businesses. To start a salt production business using geomembrane technology on one hectare of land, farmers need a total investment of IDR 81,859,000. The required components include a permanent warehouse, a non-permanent warehouse, a windmill, a pump machine, a *raca* (a traditional tool for breaking solid salt), a scale, a Baumeter (seawater salinity meter), baskets, geomembrane, geothermal plastic, bamboo, nails, and pipes. The total depreciation of the equipment amounts to IDR 6,078,583, while pond land rent costs IDR 15,000,000.

Table 6. A salt business income analysis with a tunnel.

Description	Tunnel	
	Value	%
Revenue (IDR/ha)	220,619,498	100
Operating Costs (IDR/ha)	35,160,800	100
1. Land Rent	5,850,675	16.64
2. Equipment	3,950,350	11.23
2.1. Depreciation	3,750,550	
2.2. Rent	199,800	
3. Labor Costs	21,428,670	60.95
4. Sack Costs	3,815,255	10.85
5. Others	115,850	0.33
Profit (IDR/ha)	185,458,698	84.06
R/C	5.27	

The investment costs incurred by salt farmers are one-time expenses that allow production across multiple harvests. These costs include pond preparation and the purchase of essential salt production equipment such as the Baumeter (for measuring brine salinity), windmills, and baskets. Investment in tunnel technology also requires the construction of protective structures covering the crystallization tables. These houses are built with bamboo frames and clear geothermal plastic, which ensures that the salt tables remain exposed to sunlight while maintaining stable conditions for crystallization [27].

Fixed costs for salt farmers include the annual land rental of IDR 5,850,675 and equipment depreciation used in salt production. Farmers routinely pay land rental fees to sustain their smallholder salt businesses. Variable costs cover labor and operational expenses, such as fuel for pumps. Farmers incur these costs for each harvest, calculated over the course of a year. Smallholder salt farmers typically harvest salt three to four times a month. Each harvest requires only one day and employs a standard workforce of three people. The standard labor cost for male and female workers is IDR 40,000 per workday. Transportation from the land to the truck and packing salt into sacks are calculated based on an estimated cost of IDR 5000 per sack annually.

The total annual salt production varies depending on the production technology used. Traditional and geomembrane technologies produce salt only during the dry season. In contrast, tunnel technology enables year-round production because its design allows continuous salt crystallization even during the rainy season. Salt farmers' income

depends on the salt sold to traders and middlemen. At the farmer level, the average selling price is IDR 1,050,000 per ton for salt produced using traditional methods, geomembrane technology, and tunnel technology, as these methods yield clean, white salt classified as Production Quality I. Meanwhile, salt produced using traditional Madurese methods typically sells for IDR 700,000–800,000 per ton at the farmer level.

Salt farmers calculate income by subtracting total fixed costs—such as annual equipment depreciation, annual land rental, and operational costs—from total revenue. On one hectare of land, farmers using traditional Portuguese methods earn IDR 51,152,282. Farmers using geomembrane technology earn IDR 91,430,913, while those adopting tunnel technology achieve the highest income at IDR 185,458,698.

The main advantage of tunnel technology lies in its unlimited production cycle, enabling salt farmers to produce salt even during the rainy season [28]. However, its primary drawback is the high investment cost. This significant financial requirement poses a challenge for many smallholder salt farmers, whose main priority is to meet their daily needs.

3.4.2. Smallholder Salt Businesses Moving toward Corporations with Integrated Land Production Methods

In 2011, the government encouraged salt farmers in Indonesia to form networks and establish salt business groups based on shared land locations (see **Figure 4**). The

aim was to accommodate the diverse needs of salt farmers and strengthen integration. These needs included shared infrastructure such as secondary and tertiary water channels, production roads, connecting roads, communal hold-

ing ponds, and salt storage warehouses. By organizing into groups, salt farmers also found it easier to transport salt to collection points, as they could jointly rent transportation, thereby improving efficiency.



(a)



(b)

Figure 4. Location map of salt production using integrated land in: (a) Padelegan Village (Pamekasan Regency); (b) Sentol Daya Village (Sumenep Regency).

Researchers classify farmers into three typologies: peasant, entrepreneurial, and corporate. In the context of salt farming in Indonesia, the concept of the “corporatization of salt farmers”—or more precisely, the “corporatization of smallholder salt businesses”—emerged. This concept gained traction after the 2014 salt business demonstration plot and the People’s Salt Business Development (Indonesian: *Pengembangan Usaha Garam Rakyat* [PUGAR]) program. The corporatization of small-

holder salt businesses refers to the organization of salt farming activities by farmers who apply corporate work principles^[29,30]. Under this model, an economic organization manages the business to achieve mutually agreed-upon goals. The fundamental differences between corporatized and conventional salt businesses can be seen in **Table 7** and **Table 8**, which outline distinctions in terms of management, land, technology, business orientation, and land productivity.

Table 7. The comparison of production methods for three salt production technologies on Madura Island.

Description	Salt Harvesting Based on Production Technology		
	Traditional Portuguese	Geomembrane	Tunnel (Tunnel)
Salt Crystallization Table	Made from unharvested salt during the first month.	Made of HDPE polymer geomembrane.	Made of HDPE polymer geomembrane with a bamboo frame and a roof covered in clear geothermal plastic.
Soil Preparation	Constructed from mounds reinforced with white bricks.	Formed from soil embankments.	Formed from soil embankments reinforced with bamboo.
Harvesting	Begins one month after the start of the season. Requires a chopper to break and separate the salt from the salt floor.	Can begin at the start of the season. No chopper required, as salt separates easily from the floor.	Can be carried out year-round regardless of the season. No chopper required, as salt separates easily from the floor.
Salt Quality	Production Quality I (regular harvest); Production Quality III (salt collected from the floor at the end of the season).	Production Quality I (entire harvest).	Production Quality I (entire harvest).
Harvest Period	Initial stage: 30 days; second stage: 15 days; third stage: 8–10 days.	Initial stage: 25 days; second stage: 9–10 days; third stage: 7–9 days.	Initial stage: 26 days; second stage: 10–12 days; third stage: 8–9 days.

Table 8. Differences between conventional salt farming, PUGAR, and corporatization.

Aspects	Conventional Salt Farming	PUGAR	Corporatization
Management	Individual/family	Group	Advanced group/legal entity/cooperative/Village-Owned Enterprise
Land	Fragmented; 0.3–0.75 ha or less.	Fragmented with shared infrastructure; 1.0–10.0 ha or less.	Integrated or consolidated land; 8.0–50.0 ha
Technology	Conventional methods	Screw Filter Technology	Screw Filter Technology, geomembrane, <i>bestekin</i> (geomembrane method with the addition of the sulfate in the processing).
Orientation	Meeting subsistence needs	Increasing income	Profit-oriented/maximizing benefits
Land Productivity	40–60 t/ha; Production Qualities I and II.	60–90 t/ha; Production Qualities I and II.	80–120 t/ha; Production Quality I and limited Production Quality II.

Source: Processed from various sources, 2025.

Managing Economic Organizations in Corporatization

As shown in **Table 8**, the economic organizations resulting from the corporatization of smallholder salt production may take the form of advanced salt farmer groups, People’s Salt Business Groups (KUGAR), Village-Owned Enterprises, or salt cooperatives. These organizations serve

as the key institutions that manage and coordinate salt production and business activities.

The classification of KUGAR as “advanced” has often become a topic of discussion, particularly when the question arises regarding the indicators that define it. According to Fauziyah et al.^[8], from Indonesia’s Ministry

of Maritime Affairs and Fisheries, who previously served as the person in charge of PUGAR, capital, and coastal community partnerships, an advanced KUGAR is characterized by the extensive implementation of corporatization components within the group. These include the integration of farmers' salt lands, continuous optimization of production tools and technologies, the ability to access non-government financing, high land productivity (above 90 t/ha under normal weather conditions), sound group financial management (including strong profitability), clear and structured division of labor, the capacity to establish partnerships or contractual agreements with market sector organizations (such as large cooperatives, wholesalers, associations, and factories or companies), the presence of a formal secretariat or business office, and the establishment or initial steps toward acquiring legal entity status as the foundation for a future company ^[25].

Land, Technology, and Productivity

In the corporatization of smallholder salt businesses, the relatively small plots of land owned by individual salt farmers must be consolidated into larger, unified plots ranging from 8 to 50 hectares, depending on the land holdings managed by the organization. According to a study by the Indonesian Salt Experts Association (Indonesian: *Himpunan Ahli Garam Indonesia* [HAGI]), the minimum ideal land area for producing Production Quality I salt with a reliable production volume is 8 hectares. In contrast, the average landholding of salt farmers in Madura Island is less than 1 hectare per farmer. To address this gap, the government promotes land consolidation under group management or, in some cases, through cooperatives managing larger unified plots. This approach ensures more efficient processing and better production outcomes ^[26,27].

Land integration has become a defining feature of the corporatization of people's salt in Indonesia. This process is further strengthened by the adoption of new technologies, such as Screw Filter Technology and geomembranes made from high-density polyethylene (HDPE) or low-density polyethylene (LDPE) plastics, which function as impermeable liners ^[28,29]. Production methods are also evolving with the *bestekin* technique (geomembrane method with adding the sulfate in the processing), which in-

corporates geomembranes to improve efficiency. In some areas, land consolidation is complemented with supporting infrastructure, including warehouses, salt processing units, and offices ^[30,31]. In addition, the corporatization of people's salt introduces a distinct management structure that sets it apart from conventional salt production systems ^[32,33].

The corporatization of community salt represents an organized effort by salt farmers to transform smallholder salt businesses using corporate principles. Unlike conventional peasant-based salt farming, corporatization shifts management away from individual households toward collective organizations. It integrates land, applies continuously evolving technology, focuses on profit orientation, and significantly increases land productivity ^[21]. To achieve these goals, corporatization relies on clear economic organizations, including advanced farmer groups and cooperatives— independent cooperatives and primary cooperatives linked to a parent cooperative. These three economic organizations share similarities and differences across several aspects, such as the actors involved in production, methods of production, land management authority, sales strategies, market coverage, product quality and quantity (market segmentation), and their capacity to store salt in dedicated warehouses ^[22,34].

Researchers also tested several salt samples produced on integrated land. For tunnel production, however, investment costs and location play crucial roles. According to the Head of the Maritime Affairs and Fisheries Office of Sumenep Regency, tunnels are less suitable for Madura Island due to high wind exposure. For instance, in Kalianget District and Sampang Regency, tunnels were severely damaged by tornadoes. As a result, tunnels provided by the Maritime Affairs and Fisheries Office collapsed and failed to last even five years ^[17,22].

Salt samples produced on integrated land came from Padelegan Village, Pademawu District, Pamekasan Regency, while salt samples using tunnel technology came from Sentol Daya Village, Peragaan District, Sumenep Regency. In principle, integrated land production techniques do not differ significantly from those using geomembrane-based land ^[34,35]. The key difference is scale: integrated land combines several salt fields under

a single management system, creating a larger production area and allowing more efficient use of inputs such as labor. Of the three integrated land sites on Madura Island, only the one in Pamekasan Regency remains viable. Several factors influence the sustainability of this system, including the willingness of landowners to merge their plots. In some cases, landowners refuse to participate because they would need to follow the decisions of the integrated salt land management leader^[13].

In terms of strength, the government's efforts to improve welfare through integrated land deserve recognition, since salt farmers ultimately benefit from higher land productivity and better production quality. In addition, salt farmers gain stronger bargaining power in setting salt prices, as they act collectively through formal institutions rather than as individual smallholders^[23,32]. However, in terms of weakness, land integration also raises ecological concerns. Conflicts may arise with other land uses, such as housing, while the large-scale application of geomembranes can negatively impact the environment. These risks require careful and complex consideration before further expansion of integrated land systems^[24].

4. Conclusions

If land integration within corporatization is considered the best path to land intensification, then the government and farmers must engage in more intensive communication to align their rationales and perceptions. Institutional strengthening through "farmer integration" is also necessary to optimize implementation. Contracts with factories and companies should create mutual benefits while addressing farmers' vulnerabilities. Since corporatization remains in its early stages, its ecological impacts need further research, particularly if implemented on a long-term and large-scale basis.

Author Contributions

Conceptualization, C.I.P.; methodology, C.I.P. and

A.S.J.; software, Y.P.; validation, C.I.P. and F.A.; formal analysis, C.I.P.; investigation, C.I.P.; resources, D.A.D. and M.; data curation, C.I.P.; writing—original draft preparation, C.I.P. and M.B.; writing—review and editing, C.I.P. and M.N.S.; visualization, F.A. and M.N.S.; supervision, C.I.P.; project administration, Y.P.; funding acquisition, C.I.P. and U.J. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Ethical review and approval were waived for this study because this research involve human in a minimal way. The research permit for research work was given by the Dean of the Faculty of Agriculture, Fisheries, and Animal Husbandry, Universitas Sembilanbelas November Kolaka, Number 12/UN.56D.01/PN.03.00/2024 on 10th January 2024.

Informed Consent Statement

Informed consent was obtained from all participants. Consent was implied through the voluntary completion of the questionnaire after being informed about the study's objectives and procedures.

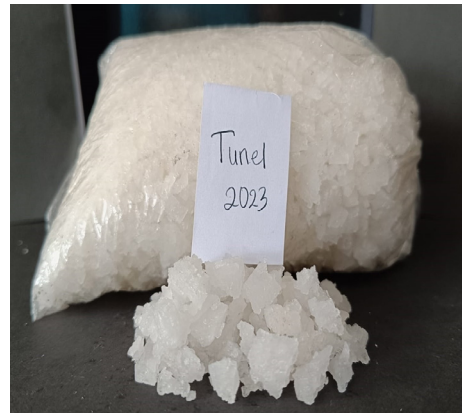
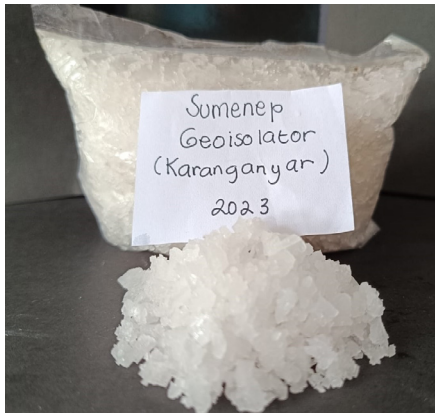
Data Availability Statement

The data presented in this study are available on request from the corresponding author.

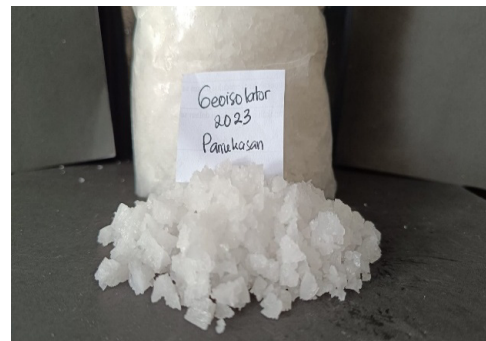
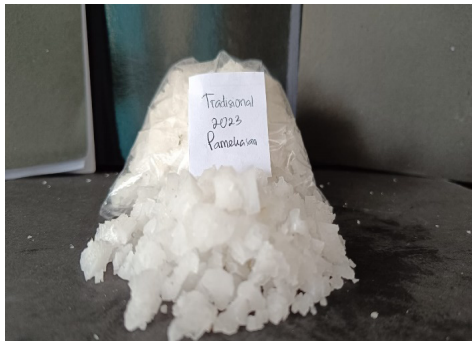
Conflicts of Interest

The author declares that there are no conflicts of interest regarding the authorship or publication of this research.

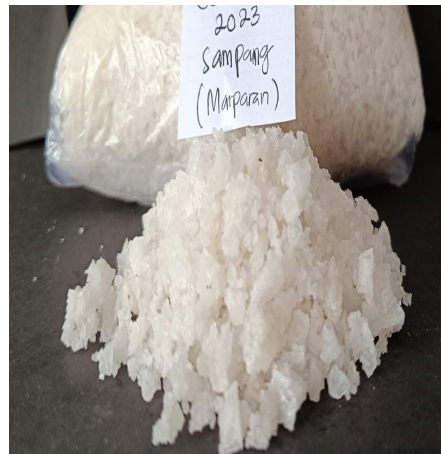
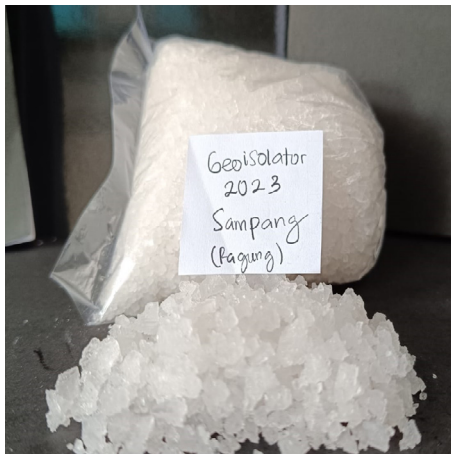
Appendix A



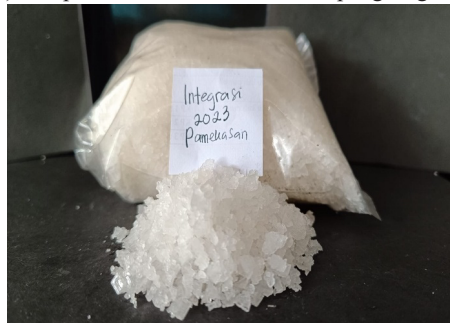
(a) Salt production results from Sumenep Regency.



(b) Salt production results from Pamekasan Regency using traditional land production methods and geomembranes.



(c) Salt production results from Sampang Regency.



(d) Salt production results from Pamekasan Regency using integrated land production methods.

Figure A1. The comparison salt results from four production methods.

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