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INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Int. J. Food System Dynamics 12 (1), 2021, 51-67

DOI: http://dx.doi.org/10.18461/ijfsd.v12i1.75

Modeling of Salt Supply Chains to Achieve Competitive Salt Prices

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Received March 2020, accepted December 2021, available online February 2021

ABSTRACT

To achieve the self-sufficiency of salt, prices need to be considered. This study develops a dynamic simulation model of salt supply chains to analyze the significant factors affecting prices from upstream to Indonesia's downstream levels. A set of dynamic simulation models is developed to achieve competitive prices using system dynamics. Furthermore, the system dynamics framework is utilized because it can model non-linear behavior between variables with a significant contribution to the system. Based on the simulation results, local and imported salt prices may compete by implementing land integration systems. This system is likely to reduce production costs and increase farmers' revenues to IDR 61,211,892 at the end of the simulation in 2035.

Keywords: *land integration; salt losses; policy; self-sufficiency; competitive price*

1 Introduction

Salt is a strategic commodity needed by households and industries. For instance, 60% of salt is used for making Caustic Soda / Chlorine, 22% for human consumption, 9% as road de-icing, and the rest for other purposes (Sedivy, 2008). Although the global salt market stood at 314 million metric tons in 2018, it was expected to surge by 1.9% annually through 2023 to 346 million metric tons (Freedonia Group, 2019). The chemical manufacturing market strongly influences the growth in salt consumption, especially in Asia. World salt production amounted to 280 million metric tons in 2017, with China as the largest salt producing country in the world. China produces around 68 million metric tons, followed by the United States, India, and Canada (USGS, 2018). Indonesia contributes around 1% of the total world salt production (Munadi et al., 2016a). It has not achieved salt self-sufficiency because production fluctuates, while demand tends to increase (Dharmayanti et al., 2013). This is attributed to several factors, including limited salt fields (about 30,000 ha), lack of technology and production depending on the weather conditions. Compared to India, land productivity and farming culture are relatively similar. However, India has vast salt fields of 145,000 ha (Nagaraja, 2015). Most of the chemical industry uses most of the salt to produce causatic soda, which is the basic raw material for making pulp and paper, textiles, soap, and detergents. The chemical industry requires high salt quality with a minimum NaCl level of 96% (Munadi et al., 2016). Most of the industrial salt is imported. Over the past five years, salt imports have tended to increase due to the chemical industry's growth rate. Figure 1 represents the demands of industrial salt in Indonesia.

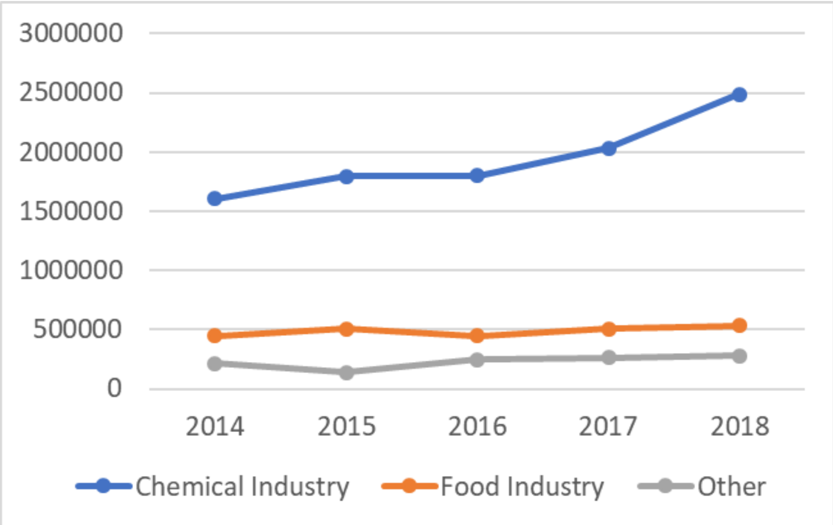

Figure 1. Industrial Salt Demands in Indonesia (Munadi et al., 2016; AIPGI, 2018)

In the past decade, Indonesia has developed a strategy for achieving salt self-sufficiency, with many studies focusing on policies for achieving these goals. Dharmayanti et al. (2013) formulated alternative policies for salt self-sufficiency. Although consumption salt self-sufficiency was achieved, industrial salt lagged. This is because of the inconsistent quality and less competitive prices (Kurniawan & Azizi, 2013). Since the profit-oriented industry uses most salt, there is a need to pay attention to price factors. Most studies have examined the increase in salt production, including Bramawanto et al. (2015) and Jaziri et al. (2017). Some have also focused on increasing salt quality, such as Arwiyah et al. (2015) and Tansil et al. (2016). However, maintaining the competitiveness of local salt against the imported one has not been examined. Salt producing countries have researched on obtaining high-quality salt at competitive prices. Notable studies include Zhao et al. (2018), Rathnayaka et al. (2013), and Nayar et al. (2019). Wenten et al. (2017) introduced the integrated processes for desalination and production to supply fresh water and salt simultaneously. The integrated processes achieve zero liquid discharge, increases water recovery, and reduces the overall desalination cost (Wenten et al., 2017). However, the price of salt produced through the proposed method has not been studied further. The aspect not studied is whether the price generated may compete with imported salt. The price of imported salt is 700 IDR/kg with high specifications (NaCl levels above 97%), making local salt uncompetitive. In case industrial salt is continuously obtained from importation, imports' value may continue to increase due to high demands. The rupiah exchange rate tends to weaken, burdening the national economy, and indirectly suppressing national salt production (Muhandhis et al., 2019). Table 1 shows the amount of Indonesian salt imports.

Table 1.
Total Salt Importation (Central Bureau of Statistics, 2019)

Year	Amount of Salts' Import (tons)	CIF Value (USD)
2013	1,922,929	88,711,500
2014	2,268,160	104,346,400
2015	1,864,049	79,831,600
2016	2,143,743	86,013,500
2017	2,552,823	83,595,200

This study develops a salt supply chain model to obtain competitive salt prices. It develops a salt supply chain model by considering internal and external factors that influence prices, right from the production, processing, and distribution, using a system dynamic. Essentially, system dynamics is a framework that offers the ability to combine expert knowledge in models and the ability to model non-linear behavior between variables with a significant contribution to the system. Dynamic model simulation can be used as a decision-making tool. Representational models describe the dynamic behavior of the system and estimate the consequences of actions with uncertainty. Simulation results are used to analyze system behavior and design and evaluate alternative scenarios for improving the efficiency of the salt supply chain to compete with the imported ones.

2 Research Methodology

This research used a system dynamics framework for modeling salt supply chains. System dynamics is a rigorous modeling method that allows building formal computer simulations of complex systems and designs more effective policies and organizations (Sterman, 2001). They can be used for modeling a dynamic supply chain, such as analyzing the price changes of each action taken on the system (Bala et al., 2019) and the effect of stakeholder behavior (Rebs et al., 2019). The simulation results can be used to determine the right policies to improve system performance. This study focuses on the goal of achieving competitive prices. Several steps of the research method are described as follows.

Step 1: Data Collection

Primary data was collected, including implementing technology, farmers' income, and production costs from observation and interview with farmers in one of the salt centers in Sumenep Regency, Madura. Interviews related to the appropriate salt production technology used in Indonesia and the losses during the factory's processing stage were conducted with relevant government agencies. Secondary data, such as salt prices, imported salt prices, average land productivity, salt fields, production, demand, total imports, and regional minimum wages, were obtained from several journal references and annual government reports. These data are used to determine each variable's parameters in the model and understand the structure of the salt supply chain in Indonesia.

Step 2: Building a Conceptual Model

A system understanding is a basic foundation for developing a causal theory about the issue. Internal and external factors influencing the salt price on the upstream and downstream levels were identified to develop a Causal Loop Diagram, which explains causal links between variables and captures the system's feedback loops.

Step 3: Building a Formal Model

Causal Loop Diagram is converted to a Stock-Flow Diagram, consisting of stock, flow, and auxiliary variables, parameters and constants, and causal links between variables and those with delay signs (Pruyt, 2013). Some parameters, behavioral relationships, and initial conditions were estimated based on the data in this stage.

Step 4: Model Validation

Model validation tests whether the simulation behavior represents a real system. In this stage, the "dimensional consistency" of the model was ensured. This involves ensuring relationships between the units in the stocks, rates, and auxiliary variables and constants make sense. We run the average comparison test statistic and the amplitude variation test to ensure the accuracy of the model (Barlas, 1986).

Step 5: Simulation Analysis and Scenario Development

A valid model is analyzed to understand system performance. The model is used to design and evaluate the proposed scenarios. Some alternative scenarios and the best scenario to achieve competitive salt prices were simulated and analyzed.

3 Base Model Development

3.1 Causal Loop Diagram

The initial stage for building a dynamic model is to determine the variables significantly affecting the system. These variables are arranged into a centralized relationship that represents a real system called a Causal Loop Diagram. The diagram shows the cause and effect of the system structure. Each arrow represents a cause and effect relationship between two variables. The '+' and '-' signs represent the direction of causality. A '+' sign can increase the result to the destination variable. Contrastingly, the '-'sign indicates can decrease the result to the destination variable. According to Haraldsson (2004), CLD is used to map the structure and feedback of a system to understand its mechanisms. The CLD's are used to understand how a behavior manifests itself in a system to develop strategies for counteracting it. Figure 2 shows the dynamic supply chain of salt in Indonesia.

Variables with a significant effect on salt prices on the upstream level include implementing technology, production costs, and land productivity. Yaqin and Setiani (2017) and Jaziri et al. (2017) stated that salt production technology's implementation increases production costs. However, it also increases land productivity (Bramawanto et al., 2015). Salt quality is determined by the production process in the field (Sedivy, 2009). The implementation of technology, such as geomembrane and filtering-threaded technology, can improve quality (Yaqin & Setiani, 2017). Generally, quality needs to be maintained because it affects the salt price at the farm level (Jamil et al., 2017). Farmers' income is derived from land productivity multiplied by the price of less production costs (Amami & Ihsannudin, 2016). The relationship between those variable forms two reinforcing and one balancing feedback loop as follows.

R1: Salt price of Farmer (+) → Farmers' Income (+) → Profit Margin of Farmers (+)→ Farmers' Capital (+) → Implementation of Technology (+) → Salt Quality (+) → Salt Price of Farmer

R2: Farmers' Income (+) → Profit Margin of Farmers (+) → Farmers' Capital (+) → Implementation of Technology (+) → Land Productivity (+) → Farmers' Income

B1: Implementation of Technology (+) → Fixed Cost (+) → Production Cost (-) → Farmers' Income (+) →Profit Margin of Farmers (+) → Farmers' Capital (+) → Implementation of Technology

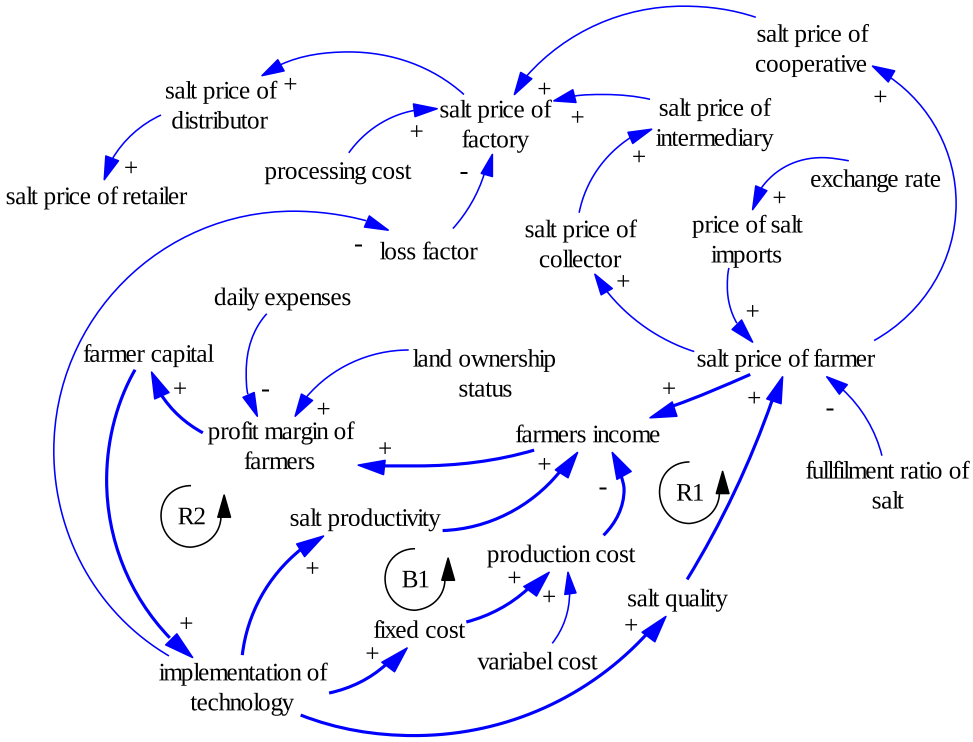

Figure 2. Causal Loop Diagram of Salt Supply Chain

The number of salt distribution actors influences salt prices on the downstream levels. According to Jamil & Tinaprilla (2015), the salt trade system starts with farmers, collectors, intermediaries, salt processing factories, wholesalers, and retailers. In the trading system, farmers get the smallest proportion of values, indicating their weak bargaining position. The trading system's profitability is gained more by collectors and intermediaries than the farmers themselves (Jamil & Tinaprilla, 2015). An important variable that affects the salt prices in the factories is the level of losses. The initial stage of processing salt consumption involves washing salt in brine with a high concentration to reduce impurities and improve its quality (Sedivy, 2009). Salt produced in Indonesia has an average loss rate of 20-30%, higher than the loss rate of imported salt from Australia by 10% (Kurniawan & Azizi, 2013). The causal loop diagrams are converted to Stock-Flow Diagrams with mathematical equations to analyze system behavior.

3.2 Stock-Flow Diagram of Salt Price of Farmer

Stock-Flow Diagram (SFD) represents the significant factor that impacts salt prices received by farmers. A multiple linear regression analysis of the dependent variable (farmers' salt prices) and two predictor variables (fulfillment ratio of salt and the price of imported salt) was conducted over the past 15 years in Indonesia. Regression analysis results showed that the VIF value was <5 for each predictor variable, hence no multicollinearity. The value of the Durbin Watson statistic (d) is 2.118, while (4-d) is 1.882. However, when calculated based on the Durbin Watson table, there is no autocorrelation. R Square value of 84.6% means that the "Farmers Salt Price" can be explained by a group of independent variables, including "Salt Fulfillment Ratio" and "Imported Salt Price" simultaneously by 84.6%, while other variables explain the rest. The salt price regression model ran through a statistics computation software and returned the following output:

Salt Price of Farmer = 61,5 + 1,01 Price of Imported Salt (IDR) - 337 Fulfillment Ratio Of Salt (1)

In case other variables are held constant, the farmers' salt price changes 1.01 per one unit of Imported Salt Price. The model also shows that the farmers' salt price decreases by 337 per one Salt Fulfillment Ratio unit. From these analysis results, all the factors that make up the salt price of farmers are external.

The salt price taken from Jamil & Tinaprilla (2015) is the farm level's average price. However, prices can be lower or higher, depending on quality. Salt with good quality, pure white with large crystal granules and NaCl levels above 95% is included in the Quality 1, which has the highest price. Contrastingly, salt with a turbid color with NaCl levels below 90% has the lowest price.

Figure 3 shows the SFD of the salt price of farmers. The "salt fulfillment ratio" is obtained from the supply divided by the salt demands. Supply is the amount of salt production plus salt stock. Demand refers to the total demands of consumption and industrial salt. "The price of imported salt (IDR)" is obtained from "imported salt prices (USD)" multiplied the "IDR exchange rate," as shown in equation (2)-(4).

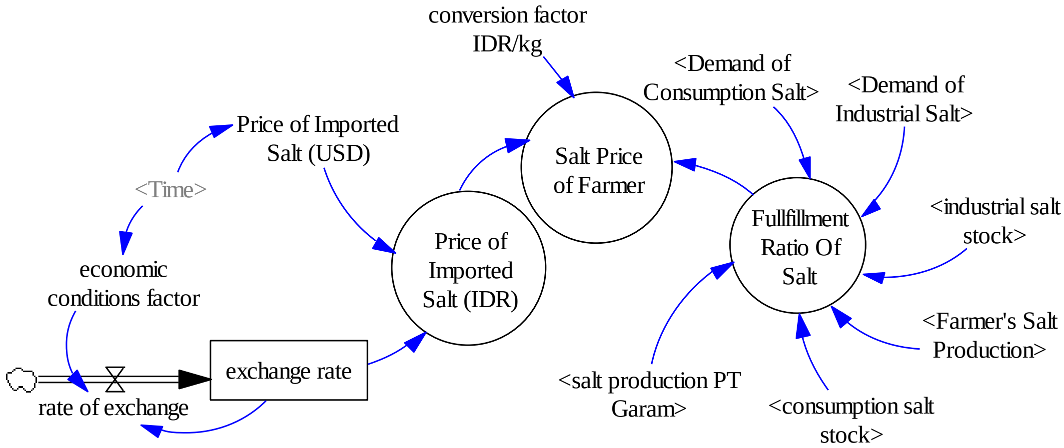

Figure 3. Stock-Flow Diagram of Salt Price received by Farmer

Price of Imported Salt (IDR) = exchange rate*"Price of Imported Salt (USD)" (2)

Fulfilment Ratio Of Salt = (consumption salt stock+industrial salt stock+Farmer's Salt Production+ salt production PT Garam)/(Demand of Consumption Salt+Demand of Industrial Salt) (3)

Salt Price of Farmer = 61,5 + 1,01 Price of Imported Salt (IDR) - 337 Fulfillment Ratio of Salt (4)

3.3 Stock-Flow Diagram of Production Cost

This SFD represents the cost of producing salt per hectare per year. Most of the salt production in Indonesia use solar evaporation. For this reason, production takes place during the dry season for 3-5 months. All external factors affecting production costs, such as inflation, government regulations related to fuel prices, and labor wages, are also included in the model.

Production costs consist of fixed and variable costs. Fixed costs consist of depreciation costs such as pumping machines and windmills, and production technologies such as geomembranes and land costs (Yaqin & Setiani, 2017; Amaliya, 2007). Variable costs consist of fuel, labor, and equipment costs (Amami & Ihsannudin, 2016). Labor costs are influenced by the number of workers needed per hectare and the number of working days (Munadi et al., 2016). Daily labor costs vary between IDR 40,000 - 60,000 (Wijaya et al., 2014), while the number of working days depends on the long dry season.

3.4 Stock-Flow Diagram of Farmers' Income

This SFD represents farmers' income per hectare per year. Sales are derived from salt production multiplied by the price. Farmers' income is derived from salt sales, less production costs. Salt farmers in Indonesia have various incomes depends on landowner status. There are three types of landowner status, including own, rent, and profit-sharing land (Kurniawan & Azizi, 2013). The highest income is obtained by farmers owning the land while the profit-sharing system offers the lowest. The profit-sharing system is a type of business that divides incomes in the ratio of 50:50 between the landowner and farmers after reduced production cost (Kurniawan & Azizi, 2013).

In this model, the flow diagram of farmers' income with a profit-sharing system due to their lower incomes is build. For competitive salt prices, the welfare of farmers with profit-sharing system is used to determine an ideal price. Farmers' profits are obtained from 50% of the salt sales due to profit-sharing system. Daily necessity refers to farmers' daily needs in one year, obtained from the Regional Minimum Wage of Sumenep Regency (as one of the salts' production centers in Indonesia) multiplied by 12 months. In this model, the "Profit Margin of Farmer" variable is part of capital inflow, while the "Daily Necessity" variable is capital outflow. Capital is derived from the profit margin minus the daily necessities. Farmer's capital is used to buy expired technologies such as geomembranes and for production costs in the following year. Figure 4 shows the SFD of farmers' income.

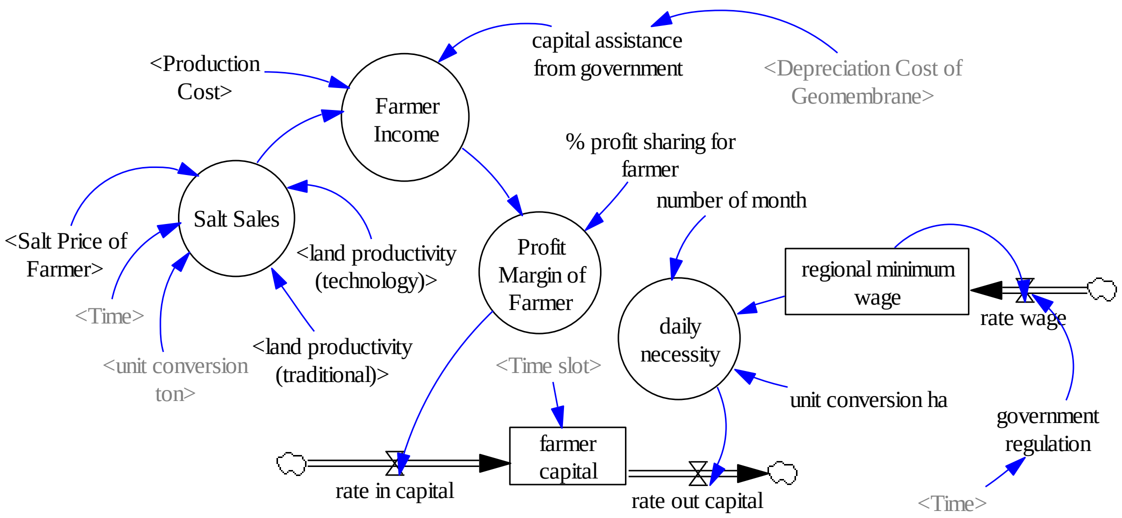

Figure 4. Stock-Flow Diagram of Farmer's Income

The equation of each variable in the model is as follows:

Salt Sales = Salt Price of Farmer*"land productivity (technology)"*unit conversion ton (5)

Farmer Income = Salt Sales-Production Cost+capital assistance from the government (6)

Profit Margin of Farmer = Farmer Income*"% profit sharing for farmer" (7)

daily necessity = regional minimum wage*number of the month/unit conversion ha (8)

farmer capital = ∫ (rate in capital-rate out capital) *Time slot (9)

regional minimum wage = ∫ rate wage (10)

3.5 Stock-Flow Diagram of Salt Supply Chain

This SFD represents the salt supply chain from producer to consumer, as shown in Figure 5. It also shows the process of price formation in each supply chain actor. Farmer's salt price is influenced by the fulfillment ratio of salt, the price of imported salt, and its quality. Furthermore, salt price in each distribution actor is formed from profits and distribution costs (Jamil & Tinaprilla, 2015) as shown in Equation (11) – (15). The more distribution actors, the more expensive the salts' price for consumers. The factory's salt price is formed from processing and distribution costs, profit margins, and the salt losses during the washing process. The interview with the salt factory shows the average salt loss rate in Indonesia is 28%. This means that every 100 kg of washed salt produces 72 kg of clean salt ready for processing.

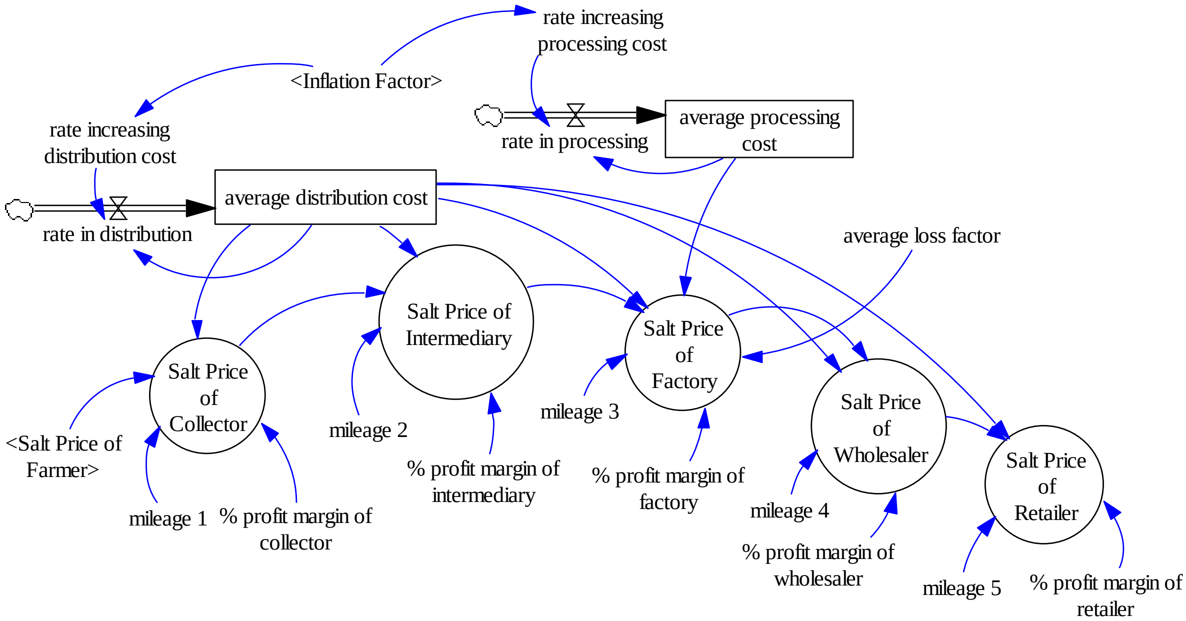

Figure 5. Stock-Flow Diagram of Salt Supply Chain

Salt Price of Collector = (Salt Price of Farmer*"% profit margin of collector") + (average distribution cost*mileage 1) +Salt Price of Farmer (11)

Salt Price of Intermediary = Salt Price of Collector+(Salt Price of Collector*"% profit margin of intermediary") +(average distribution cost*mileage 2) (12)

Salt Price of Factory = (Salt Price of Intermediary+(average distribution cost*mileage 3) + (Salt Price of Intermediary*"% profit margin of factory") +average processing cost)/ (1-average loss factor) *1 (13)

Salt Price of Wholesaler = Salt Price of Factory+(Salt Price of Factory*"% profit margin of wholesaler") +(mileage 4*average distribution cost) (14)

Salt Price of Retailer = Salt Price of Wholesaler+(Salt Price of Wholesaler*"% profit margin of wholesaler") +(average distribution cost*mileage 5) (15)

3.6 Model Validation

The dimension testing ran through our simulation software. The results show that there are no inconsistencies. Models' structure testing through simulation software shows that the structure of the model is valid. To measure the accuracy of the model, system validation can be conducted in two ways. The first one involves the average comparison test statistic or means comparison, while the second one is the model validation by comparing the amplitude variation test or percentage of error variance based on Barlas (1986). The model is considered valid in case the mean comparison is (E1) ≤ 5%, and error variance is (E2) ≤ 30%. Mean comparison and error variance are defined in Equation (16) and (17).

$$E1 = \frac{\bar{S} - \bar{A}}{\bar{A}} \quad (16)$$

$$E2 = \frac{|Ss - Sa|}{Sa} \quad (17)$$

Where:

$\bar{S}$ = the average rate of simulation

$\bar{A}$ = the average rate of data

Ss = the standard deviation of simulation

Sa = the standard deviation of data

In this research, the average simulation results are compared with the real data for the 2004-2018 period. Table 2 summarizes the E1 and E2 validation results.

Table 2.
Validation of significant variable in the system.

Variable	Average Mean of Simulation	Average Mean of Data	Mean Comparison (E1)	Average error variance of simulation	Average error variance of Data	Error Variance (E2)
Land Productivity	74.93	74.46	0.61%	30.41	38.85	21.73%
Salt Production	1,372,566	1,372,707	0.01%	751,605	773,141	2,79%
Salt Demand	3,409,479	3,409,887	0.01%	314,611	330999	4.95%
Salt price of Farmer	461	459	0.41%	203	220	7.8%
Price of Imported Salt (IDR)	465	464	0.13%	164	165	0.51%
Salt price of Retailer	3800	3856	1.45%	1193	1494	20.11%
Regional minimum wage	886470	889389	0.33%	406649	405720	0.23%

Based on the calculation in Table 2, all the mean comparisons are less than 5%, while the error of variance is less than 30%, meaning the model is valid.

4 Base Model Simulation Analysis

Salt sales are included in the perfectly competitive market, with many sellers and buyers and homogeneous product types. Figure 6 compares the farmers' salt price and the price of imported salt in the last 15 years. The average farmers' salt price is almost the same as the price of imported salt. However, local salt has a high loss rate of 28%, while the import salt loss rate is relatively low at 10%. For this reason, imported salt is preferred by the market. Additionally, the local salt quality is not consistent, unlike imported salt with NaCl levels above 97% (Budget Study Center, 2016).

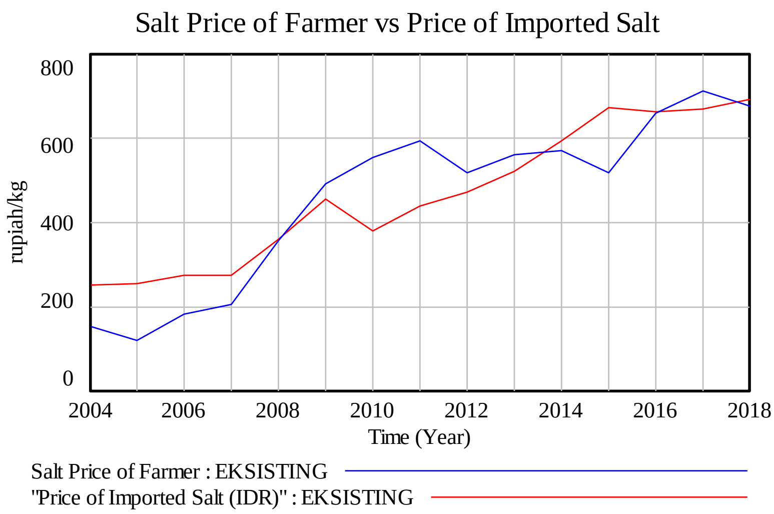

Figure 6. Comparison between farmers' salt price and price of imported salt

Table 3 summarizes the results of the base model simulation. The long dry season has a positive effect on land productivity because most of Indonesia's salt production uses the solar evaporation method (Jaziri et al., 2018). This means rainfall has a negative and significant effect on the salt supply (Rusdi, 2018). Different rainfall in coastal areas significantly affects land productivity (Purbani, 2006). Production costs increased significantly from 2011 due to the implementation of technologies, such as filtering-threaded and geomembrane (Dharmayanti et al., 2013). The technology was implemented massively by farmers through PUGAR policy. In general, PUGAR is a program held by the Marine and Fisheries Ministry since 2011. It aims to increase farmers' salt production by improving production technology, increasing infrastructure, and expanding land for cultivation. PUGAR policy has successfully increased salt productivity (Muhandhis et al., 2019). The use of production technology increases land productivity and significantly boosts income (Bramawanto et al., 2015).

Table 3.

Summary of Base Model Simulation Results

Year	Long Dry Season	Land Productivity	Price of Imported Salt	Salt Price of Farmer	Farmers' Income	Production Cost	Daily Necessity
	(months)	(tons/ha)	(IDR/kg)	(IDR/kg)	(IDR/ha)	(IDR/ha)	(IDR/year)
2004	6.8	78	252	154	2,038,671	9,971,795	4,752,000
2005	5	54.6	254	122	-1,071,324	7,713,243	5,084,640
2006	6	67.6	274	184	2,162,339	10,287,973	5,847,336
2007	5.3	58.5	275	204	1,712,694	10,244,444	6,490,543
2008	4.6	49.4	360	358	7,128,528	10,534,285	7,009,787
2009	5	54.6	455	493	14,520,502	12,413,249	8,201,450
2010	1.8	13	381	555	2,208,360	5,007,541	8,693,537
2011	5	81	438	595	33,848,292	16,846,544	9,389,020
2012	5.8	95.4	472	518	32,179,648	19,741,274	9,858,472
2013	3	45	522	560	15,142,503	12,554,248	11,534,412
2014	6	99	594	571	36,521,476	22,510,376	13,033,886
2015	6	99	675	520	30,344,852	23,641,280	14,988,969
2016	1.5	18	665	661	5,186,486	9,211,390	16,787,646
2017	4	63	669	714	29,091,964	18,396,026	18,130,658
2018	6	99	692	677	42,823,360	26,648,002	19,762,416

Land productivity has a positive effect on farmers' income. Some farmers implement a profit-sharing system with landowners, where the profit margin is obtained from 50% of their income. According to Figure 7, farmers with profit-sharing system have low profits. Sometimes the profits are below their daily needs in one year. During the short dry season, the profits decrease, and therefore, living costs are not fulfilled. Febryanti (2013) stated that the conversion of salt fields is also caused by the low income of farmers. According to Setiawan (2019), the salt farmers' welfare is low. The Marine and Fisheries Ministry Annual Reports (2016) stated that the salt production target in 2015 was not achieved due to fluctuating salt prices. When the price of salt rises to improve farmers' welfare, the users from industry (food industry, CAP industry, etc.) prefer imported salt (Kurniawan & Azizi, 2013). Therefore, prices should be ideal for both farmers and users.

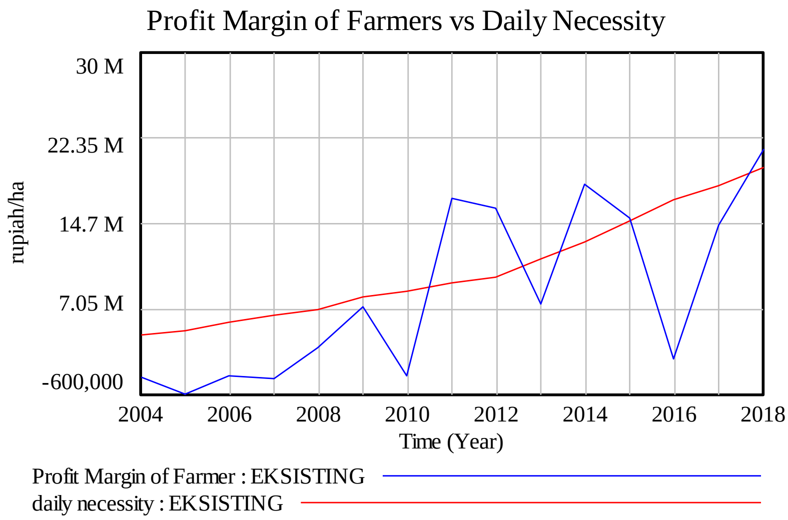

Figure 7. Comparison graph between the profit margin received by farmers and their daily necessity for one year

The above analysis shows that the variables that significantly influence farmers' income include salt prices, land productivity, and production costs. Salt price is influenced by external factors, which can be reduced by cutting production costs. Therefore, several scenarios are developed to increase land productivity, reduce production costs, and improve salt quality and supply chain efficiency for competitive salts' price.

5 Scenario Development

Once a valid model has obtained the structure of a valid model, the parameters can be modified to improve the system performance. A scenario is not a forecast or an intention to describe a certain future state. However, it is intended to provide a possible set of future conditions. An optimistic scenario is provided to achieve a competitive salts' price. The scenario is based on a strategic plan from the stakeholders. Three alternative scenarios (land integration, land intensification, and supply chain efficiency scenarios) are combined in one strategic step, the Land Integration System Management.

On its web site, the Marine and Fisheries Ministry plans a land integration system management to increase salt production. The management is conducted by incorporating a minimum of 15 hectares of salt fields in one unified production process. The main principle in land integration is to synergize raw material production, processing, and marketing activities in one large activity to increase product added value, increase the value of products, and boost profits. Salt producing countries, such as Australia, have a thousand acres of land in one production area, used as crystallizers and evaporators. A large salt field increases production efficiency through process modernization, making the price of salt competitive. The land integration management system is implemented as a manifestation of *corporate farming*, *capitalist farming*, or *contract farming* (Baekhaki et al., 2018.). Wittmaack (2006) stated that the corporation produces a consistent output and capitalizes on economies of scale. Factory-style corporate structured farms produce more output for less money, decreasing product prices, and making them competitive in the global market (Wittmaack, 2006).

Observations were made in one of the integrations land in Sentol Daya Village, Sumenep Regency. The land belongs to the headman, though it is cultivated by a farmer group of 10 people. Production capital is obtained from local cooperatives. The farmer group pays the capital installments through profit-sharing of around 10% from the cooperative. Income is obtained by sharing with the landowner in the ratio of 50:50.

The total integrated land area is 16.5 hectares, divided as 1.5, 2.3, 12.2, and 0.5 hectares for crystallizers, water bunker, evaporators, and tunnel system, respectively. Water bunkers, which have a depth of 1.5-2 meters, are used to hold the seawater of 5-10^0 Be (Baume). When the dry season arrives, seawater in a water bunker can be processed immediately to accelerate salt production. Salt is produced using filtering-threaded technology, geomembrane, and tunnel systems. With a large cultivation area, the salt production increases because seawater evaporation is faster with filtering-threaded technology. Specifically, the technology is a modified evaporation pond that involves passing water through a series of shallow channels to saturate the water into brine with an additional filtering membrane for purification (Jaziri et al., 2018; Bramawanto et al., 2015). Geomembrane technology involves lining the crystallizers with appropriate plastic membranes (Jaziri et al., 2018). These two technologies are used to improve salt quality and reduce impurities. For a high salt quality (NaCl above 97%), brine concentrates at least 27^0 Be when entering the crystallizers and harvested at a maximum of 29^0 Be.

The land has 13 units of tunnel systems. In general, a tunnel is a type of greenhouse used to produce salt during rainy seasons. The solar tunnel is commonly used for farming products, such as fish, to stop bacteria rate processes (Swati *et al.*, 2015). In the salt production, it escalates sunlight radiation and enhances solar collector efficiency applied as an evaporation pond and crystallizer. It also increases brine concentration 1^0 Be within 2-3 days during the rainy season. Each tunnel produces 600-750 kg of salt every 10-14 days in the rainy season. The tunnel system installation is only 0.5 hectares, hence does not contribute significantly to land productivity.

With all these technologies, land productivity increases from 90-125 tons/ha in 170 days of the dry season. Salt production in this integrated land reaches 1500 tons in 2019. Table 4 shows the production costs of the integrated land. However, the land requires modernization of the production process or technological innovation to increase productivity. Bramawanto et al. (2015) modified the salt field by changing the reservoir ponds into large-threaded evaporators to increase brine supply. This is achieved by increasing the evaporator area up to 247% to speed salt crystallization. Land modification can be conducted in an area of at least 5 ha. Therefore, land integration systems can implement this strategy. The land modification experiment results conducted by Bramawanto et al. (2015) increased productivity to 200 tons/ha.

Table 4.
Production costs on integrated land for one year.

Variable	Cost (IDR)
1. Depreciation Cost:	
1.1. Geomembrane	37,500,000
1.2. Large Pump Engine	5,000,000
1.3. Small Pump Engine	3,750,000
1.4. Tunnel System	10,833,000
1.5. Windmill	750,000
1.6. Supporting Equipment	1,370,000
2. Maintenance Cost	600,000
3. Fuel (6 months of the dry season)	9,000,000
4. Land Tax	825,000
Total Cost	**69,628,000**

Table 4 shows production costs on integrated land in one period. The cost of preparing land and labor during the salt production process is not calculated because production is conducted by the farmer groups and profits shared among members based on their work portion. Overall, production costs of integrated land are cheaper than the costs incurred by farmers if the land is managed individually. Figure 8 shows a comparison between production costs on integrated and individual land.

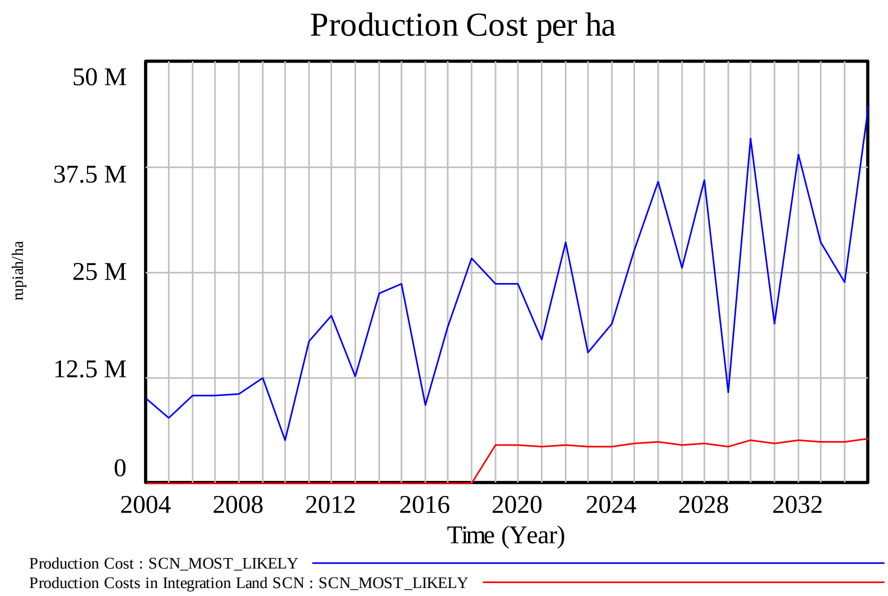

Figure 8. Comparison of production cost in the integration of land and individual land

A salt price scenario is proposed to determine the ideal price for both farmers and users. This is a price that meets the needs of farmers' lives without burdening consumers. Logically, consumers prefer lower prices. Therefore, the price of salt at the farm level should not be higher than competitors. The farmers' salt prices 20% cheaper than the price of imported salt is determined to attract market interest. Table 5 summarizes the price of imported salt projection and the proposed farmers' salt price scenario.

Table 5.
Price of imported salt projection and proposed farmers' salt price scenario (IDR/kg)

Year	Price of Imported Salt Projection	Salt Price Scenario
2020	741	593
2021	767	613
2022	794	635
2023	822	657
2024	850	680
2025	880	704
2026	911	729
2027	943	754
2028	976	781
2029	1010	808
2030	1045	836
2031	1082	865
2032	1120	896
2033	1159	927
2034	1200	960
2035	1242	993

Figure 9 represents the results of the simulation of land integration and salt price scenarios. Farmers' profit increases because of a significant reduction in production costs. Overall, profits are still feasible. The long dry season parameter is generated randomly between 1-6 months. Therefore, land productivity fluctuates, varying farmers' income. In the short dry season, such as 2029, 2031, and 2034, farmers' income decreases. However, their profit margin can fulfill their daily needs, as shown in Figure 9. Profits obtained during the long dry season can be saved and used when salt production decreases due to unpredictable weather conditions.

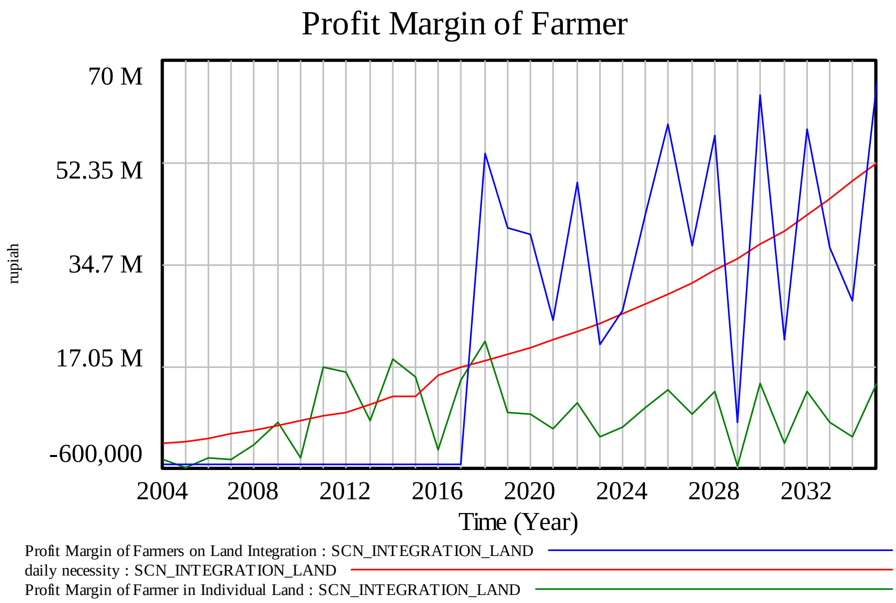

Figure 9. Comparison of production cost in the integration of land and individual land

The current supply chains lack efficiency due to many intermediaries existing between the Farmer and the salt factory and between the salt factory and the consumer, leading to greater complexity, lower efficiency, reduced margin, and increased cost on the product (Lin et al., 2011). A supply chain efficiency scenario is provided to reduce the supply chain actors. The existence of farmer groups is expected to increase the bargaining position of farmers. Unity among active farmer groups replaces the position of collector and intermediary. Therefore, farmer groups may directly sell salt to factories (Jamil & Tinaprilla, 2015). Figure 10 shows the structure of the supply chain efficiency scenario model.

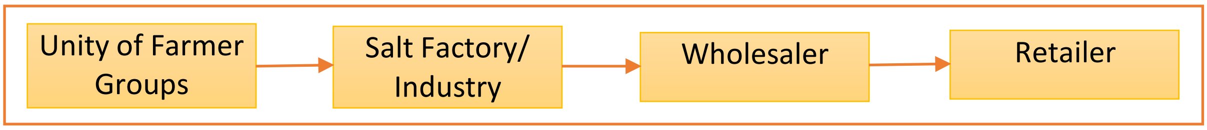

Figure 10. Structure of Supply Chain Efficiency Scenarios (Jamil & Tinaprilla, 2015)

The unity of farmer groups has several advantages. For instance, it facilitates market access and strengthens farmers' bargaining position in trade to sell their products directly to the factory (Jamil & Tinaprilla, 2015). Additionally, they sell large quantities of salt with uniform quality preferred by factories. This is because it is easier to manage and identify the quality of salt.

According to Fisher (1997), it is vital to understand the nature of the product and design a supply chain based on its nature. In general, there are two basic types of products, including Functional and Innovative, with appropriate matching supply chains as efficient and responsive (Fisher, 1997). Salt is a Functional product since it meets several criteria, including slight product variations, contribution margins between 5-20%, product life cycles more than 2 years, and the average margin of error in the forecast at the time of production being around 10 %. Thus, companies that make such products are free to focus almost exclusively on minimizing costs, including the expenses involved in salt purification. With the implementation of production technology and the right crystallization time, the salts produced is of high quality with NaCl levels above 97%. This improvement is expected to reduce the loss rate during washing at the factory to a maximum of 20%. Sedivy (2009) examined salt purification with a low loss rate of 3.9%. Rathnayaka *et al*. (2013) studied how to develop a process that increases the NaCl percentage of crude salt from conventional solar evaporation. The purified salt obtained was 99.60% NaCl and increased profits by 112.3% compared to the traditional process (Rathnayaka et al., 2013). This research needs to be reviewed to minimize salt price during the washing at the factory, especially in Indonesia. According to Sedivy (2008), high salt purification is costly. From the land integration results, improvement salt quality, salt price scenario, and supply chain efficiency scenario, the price of salt at the retailer decreased by 20%.

6 Conclusion

A good understanding of the system is required to build a system dynamics model. System dynamics is an appropriate method that allows the building of formal computer simulations of salts supply chain and designs more effective policies for competitive prices. From the simulation results of the base model, production cost, land productivity, and technology implementation are significant variables affecting the salt price at the upstream. The number of distribution actors in the trading system and the loss rate during washing at the factory are significant variables that affect the salt price downstream. To obtain competitive salt prices, a land integration system management scenario needs to be developed. These scenarios' time frame is expanded until 2035 for more time to learn about the system behavior and proposed strategic steps to achieve competitive salt prices.

By implementing land integration system management, local salt may compete with the imported salt in terms of prices. Integrated land may reduce production costs and increase farmers' income to IDR 61,211,892 at the end of the simulation in 2035. The proposed salt price benefits not only farmers but also users. By implementing filtering-threaded technology and geomembrane on land integration, the land productivity reaches 90-125 tons/hectares. High salt quality can be achieved using these technologies along with the right crystallization time. By implementing salt price and supply chain efficiency scenarios, unity of farmers' groups may directly sell salt to factories and decrease retailer prices by 20%. Additionally, by applying all the scenarios mentioned above, local salt may compete with imported, dominating the domestic market to attain self-sufficiency.

A scenario for minimizing salt prices is developed in terms of production and distribution. Future research needs to focus on minimizing salt prices from the factory's processing stage, how to obtain high salt purification at competitive prices, especially in Indonesia.

Acknowledgment

This research is a collaboration between Universitas Wijaya Putra (UWP) and Institut Teknologi Sepuluh Nopember (ITS), supported by Directorate of Research and Dedication to Society (DRPM).

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