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RESEARCH PAPER

Revenue Farmer Assessment Using System Dynamics Approach: Seablite Salt (*Suaeda Maritima*) Production Case Study

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ABSTRACT

Seablite salt (Suaeda maritima) is a unique product currently under development providing a low-sodium alternative essential for modern society, particularly for those prioritizing health. Therefore, this study aimed to use system dynamics method to evaluate revenue and profit generated by salt production system. The method included the following steps such as constructing the causal loop diagram, developing the stock-and-flow model, parameterizing the model, simulating to analyze system behavior under various conditions, verifying and validating, advancing policy recommendations, as well as concluding with a summary of the core results. Furthermore, four sub-models were used in developing the framework, namely demand, supply, production cost, and revenue. The results found two scenarios of the model namely moderate and optimistic. Moderate scenario showed that salt flow requirements could be satisfied by using system dynamics method to protect revenue and manage production costs, consistent with escalating production expenses. According to optimistic scenario, salt demand could be satisfied until 2026. However, revenue of company was insufficient to cover production costs due to rising raw material prices. This caused the farmers to begin benefiting in the scenario as overall revenue exceeded production costs.

KEYWORDS: Demand; System dynamics; Production cost; Revenue; Farmer; Seablite salt; Supply; Suaeda maritima.

1. Introduction

Salt production is a crucial industry in Indonesia with an average national production of 2.5 million tons annually [1]. However, the production level does not meet the increasing domestic demand driven by the increasing population and industrial development. Salt produced by farmers is produced daily which is divided into table and healthy low-sodium salt. Both of these salts produced by farmers are distinguished by NaCl content [2]. Salt industry cannot only provide consumption of salt needs but will also have an economic impact on the surrounding community [3]. A form of salt industry that positively impacts the economy and the environment is the production of healthy or dietary salt. This low-sodium salt is an additive in food and can further benefit the body of the individuals. Low-sodium salt is a growing need in modern society with increasing awareness of the dangers of excess consumption [4]. Therefore, a promising method to reduce sodium intake is to develop low-sodium food products [4–7][8], and an alternative raw material that can be used for healthy salt is Seablite plant (Suaeda Maritima).

Seablite plant originates from coastal areas, absorbing salt from the surrounding environment which is further extracted to produce a specific type of salt. Seablite is a plant that has the potential to be developed as salt substitute [9–11]. The production of Seablite salt is effortless which includes washing, soaking, and re-drying [12]. This process provides new opportunities for coastal communities to increase income and the

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production will reduce salt dependence on seawater. Using Seablite crops in salt production has a positive environmental impact as the cultivation does not require evaporation of seawater or extraction of salt from rock salt deposits. Seablite salt will have ecological benefits, nutritional value, and challenges associated with the production and commercialization.

The production process of a new product presents particular challenges for businesses with revenue being a crucial factor as well as others including the production process, number of sales, raw materials, etc. The amount of revenue significantly affects profitability and motivates the sustainability of the production process [13,14]. Therefore, profitability is defined as the net result of various company policies and decisions. It is a factor that needs significant attention because the ability of company to generate profits is essential for long-term survival and growth. Profitability ratio can also measure company ability to generate profits from operating activities [15]. Furthermore, revenue value measurement can depict the level of business productivity and also informs pricing, production scheduling, as well as resource allocation which supports continuous improvement efforts and evaluation of new technologies or processes [16,17]. Several key factors affect salt production levels during the process including capital, labor, land area, and land ownership. The availability and accessibility of these resources play an essential role in determining salt production crops and profitability [18].

In this context, revenue assessment can be modeled using system dynamics method which is widely used in various fields as it is a versatile framework for understanding and analyzing complex phenomena [19]. Dependencies, mutual interactions, information feedback, and causal cycles are the characteristics of any system dynamics. The method starts by defining the problem dynamically over time, modeling the significant variables, and developing stock and flow diagrams [20]. It can also integrate various financial and operational factors in a comprehensive model [16]. A critical consideration in system dynamics modeling is the need to view an industry as an interconnected system with various business processes and functions interacting hierarchically. This multidimensional perspective allows organizations to project the impact of new technologies or changes on overall productivity by mapping relationships between processes, functions, and overall business strategy.

Several publications have carried out system dynamics method on salt commodities, discussing prices, increasing the income of salt farmers, and supplies [21–25]. Numerous studies have also used this method to model revenue of the production process [26–31], the amount of profit earned, and the scenarios used to maximize profits [21,32–40]. System dynamics method is further used to cluster agriculture-based regions [41]. Part of the challenges in salt production is natural conditions [42–44]. However, no study has discussed revenue assessment of salt production model using system dynamics method.

This study is significant in understanding revenue farmers will obtain when developing Seablite salt production. As a new product, an overview of revenue level and the various scenarios is required. Therefore, this study aims to analyze revenue level based on the amount of profit in salt production framework with system dynamics method. Revenue level is also assessed to determine the best scenario for maximizing salt farmer profit. Dynamics model developed in this study used various internal and external factors that affect salt farmer revenue such as demand, supply, production costs, and total income. The interaction among these factors will be simulated to determine the efforts that can be made to improve the welfare of salt farmers.

The prospects for developing the Seablite salt industry are fundamentally understood through the study. The development of this industry is not only determined by production costs and product prices but also influences demand for healthy salt, the population, and the availability of raw materials. Demand for seablite salt is an opportunity to develop Seablite salt industry which will provide employment opportunities and increase revenue of coastal communities.

2. Literature Review

2.1. Seablite salt

Seablite salt represented a coastal plant rich in minerals and had a relatively low sodium content. Additionally, it contained various antioxidant compounds that could help neutralize free radicals and reduce cell as well as tissue damage [45]. These properties prompted Suaeda maritima to be an up-and-coming alternative to replace conventional table salt, specifically for hypertensive patients who needed to limit sodium intake [8]. The lower sodium and high content of other minerals such as magnesium as well as calcium prompted the salt to be better for human health [12][46]. Besides containing good nutrition and low salinity content, Seablite salt had anti-inflammatory and antioxidant content [47–49], thereby becoming a healthier and higher value-added alternative to ordinary salt consumption.

The production of Seablite salt provided a solution for extracting valuable minerals from saltwater which contributed to a more circular and sustainable resource management method [50,51]. Furthermore, Seablite crops produced 25% salt by extraction method [52] including a NaCl content of 5.456% to 6.625%, a vitamin A content of 0.996 µg/gram to 1.380 µg/gram, and a salinity that ranged from 3.006% to 1.943 [12,53].

In the production process of Seablite salt, considering various aspects was essential such as the selection of appropriate raw materials, an efficient crystallization process, and standardization of the quality of the final product. Various improvement and development efforts were also essential to increase the crops and quality of salt following consumer preferences [9,54]. Studies on Seablite salt needed to be explored and developed for further publications [8,55–57] which was currently in the phase of characterizing the product. Furthermore, the enhancement of Seablite salt in an industry had not been undertaken due to the absence of publications on scaling up output. There were no articles conducted on the expansion of production capacity. Developing the Seablite salt industry required a thorough analysis of consumer preferences for this product. The calculation of the added value and selling price of Suaeda maritima had not been studied.

2.2. System dynamic

Several publications developed salt models with system dynamics method which showed the relationship between Salt Lake mineral resources, ecological environment, socio-economic development, and future trends [1]. The identification of existing problems in salt industry and factors significantly affecting the national salt production system were represented in dynamics model [24]. Additionally, system dynamics were created to model the fulfillment of the amount of salt to meet industrial salt standards which was absorbed by the industrial sector in Indonesia [58]. Salt supply chain model with system dynamics was similarly used for price analysis from upstream to downstream levels [59].

In this study, system dynamics were used to model the amount of total revenue [21,32–40] and develop production as well as profitability models in predicting the uncertainty of water inflow status and electricity prices [35]. Additionally, these models were used to build e-commerce business frameworks for effective marketing systems [60]. Business models with partnership scenarios were conducted to determine consumer behavior for profit modeled by dynamical systems [61]. In this context, pharmaceutical supply chain modeling stated that the strategy to increase profits was to pay attention to collaborative relationships with suppliers, investment in new technologies, and the establishment of information technology [62]. Dynamics model was further created to conceptualize business modeling for sustainability methods, combining a customized sustainable business model canvas and system dynamics modeling [63]. The model-based strategy used system dynamics to help managers and stakeholders in small and medium enterprises (SMEs) clarify possible paths and to offer a framework for understanding, guiding, and generating future strategies [64]. Publications on system dynamics that discussed the process of Seablite salt production determining the amount of income did not exist, stimulating the importance of this study.

3. Material and Methods

3.1. Material

In this study, material used was Seablite salt with the production process starting from the manufacturing of the flour. Producing the flour included sorting Seablite leaves with stems and other components, followed by washing. The next stage was blanching for 3 minutes and drying at 65oC for 3 days. The final stage was the size reduction and sieving process. The resulting Seablite flour was used as raw material to produce salt which was dissolved and filtered with distilled water solvent. The obtained filtrate was further dried and called Seablite salt.

3.2. Methods

System Dynamics (SD) represented a method of analyzing and designing a policy as well as modeling and simulation of complex systems. Sterman described system dynamics as an aid to learning and understanding complex systems [20], emphasizing how the modeling process consisted of (1) tools to elicit mental models of systems, (2) procedures to create formal models based on the mental models, (3) computer simulations of the formal models, and (4) applications of the results of the simulations to improve understanding of system. Consequently, this study adhered to the following multi-step methodology to develop system dynamics model [65][66]:

1. Constructed the causal loop diagram to

represent the feedback mechanisms and interdependencies in system.

2. Developed the stock-and-flow model to quantify dynamics relationships between the variables. This study adhered to a multi-step methodology in developing system dynamics model starting with identifying key variables and the relationships in demand, supply, cost production, and total revenue. Subsequently, the causal loop diagram was constructed to represent the feedback mechanisms and interdependencies in system.
3. Parameterized the model adopting data from various sources including field surveys, historical records, and relevant literature.
4. Fostered the model to analyze system behavior under different scenarios and identified potential leverage points to improve revenue of salt farmers and the sustainability of Seablite salt production.
5. Verified and validated the accuracy and reliability of the model through sensitivity analysis and comparison with empirical data. Model verification was carried out to ascertain when the model was developed according to what was agreed. The model would be validated when it passed the verification process. Validation was further carried out by comparing the behavior of system model with the actual conditions. Comparisons were made with the MAPE (Mean Absolute Percentage Error) test which concerned the percentage of error in system model [60], [61]. MAPE calculation was performed through the following formula.

$$MAPE = \frac{1}{n}\sum\frac{|Xm-Xd|}{Xd} = 100\% \quad (1)$$

6. Developed policy recommendations based on the insights gained from system dynamics method. The scenarios that were used in this study were optimistic, moderate, and pessimistic scenarios. Optimistic scenario described the conditions of salt flow demand and raw material costs that increased from current conditions. It also explained the variables affecting salt flow production system when there was an increase in one or more variables. In comparison, moderate scenario was a situation that could occur in the future with everything remaining the same as the current conditions. In the production of Seablite salt, the scenario explained the variables of demand and raw material costs by current conditions. Furthermore, pessimistic scenario described a condition where demand for raw material prices dropped from the present. Similar to optimistic, pessimistic scenario affected the amount of salt produced, production costs, and revenue.
7. Concluded with a summary of the essential results and the implications for Seablite salt production.

4. Model Development

4.1. Causal loop diagram

The cause-effect chart showed the relationships between the 49 identified variables as depicted with arrows. Each arrow was assigned a polarity, either positive (+) or negative (-) depending on the interaction between the variables. Blue arrows were denoted as positive (+) while red represented negative (-) relationships. The sign (II) on the arrow showed a delay in the relationship between the variables.

The causal loop diagram of salt flow production system was depicted in **Fig.** 1**.** The diagram explained that market demand for Seablite salt directly affected revenue. Furthermore, revenue from the sale of Suaeda maritima also directly affected the profit earned. Market demand for Seablite salt was also found to indirectly affect the number of raw materials used. The number of Seablite crops directly affected the price of furrow crops. Additionally, the market demand affected the production of Suaeda maritima where higher market demand led to greater production. The production significantly affected revenue level of Seablite salt sales.

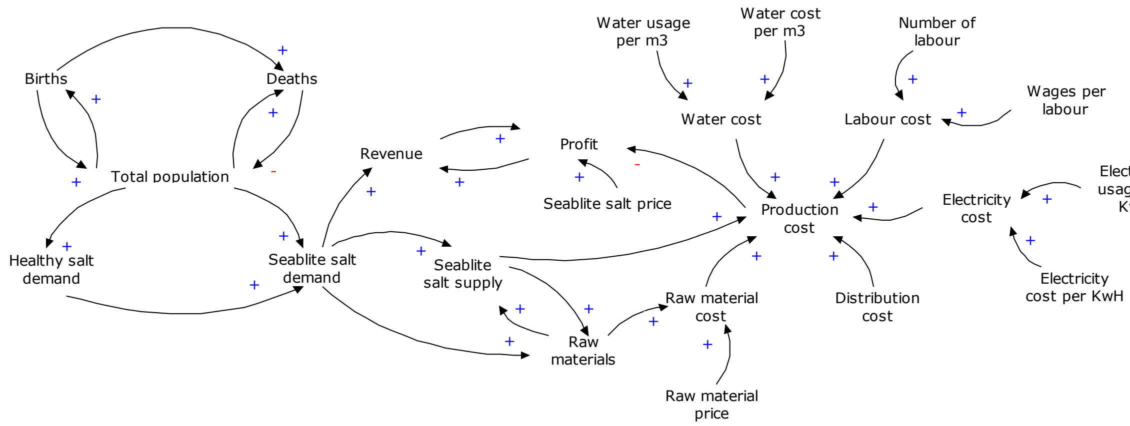

Fig. 1. Causal loop diagram

4.2. Stock flow diagram

Stock and flow diagram was divided into four sub-models namely (1) demand, (2) salt flow availability, (3) production cost, and (4) revenue. The determination of sub-models or variables in dynamics salt flow production system was based on previous publications. Production costs, demand, and salt flow availability were found to affect the results of revenue projections. However, the variable income or sales affected the output element to be achieved namely profit [67,68]. Stock and flow diagram of salt production revenue was depicted in **Fig.** 2. The diagram explained that salt farmer income level was influenced by the amount of demand, availability of supply, and the cost of Seablite salt.

4.2.1. Demand sub-model

The model of demand for Seablite salt was assumed to be 10% of demand for healthy salt namely low-sodium salt produced by PT Garam (Persero). The number of low-sodium salt sales influenced this sub-model with the population also affecting the sales. Demand for Seablite salt was further influenced by demand for healthy salt and population. Demand for healthy salt was further influenced by population where more population led to higher demand for Seablite salt. Births and deaths were also found to influence the total population. When the number of births increased, death would further reduce the population. The number of populations possessed the potential to increase the number of deaths.

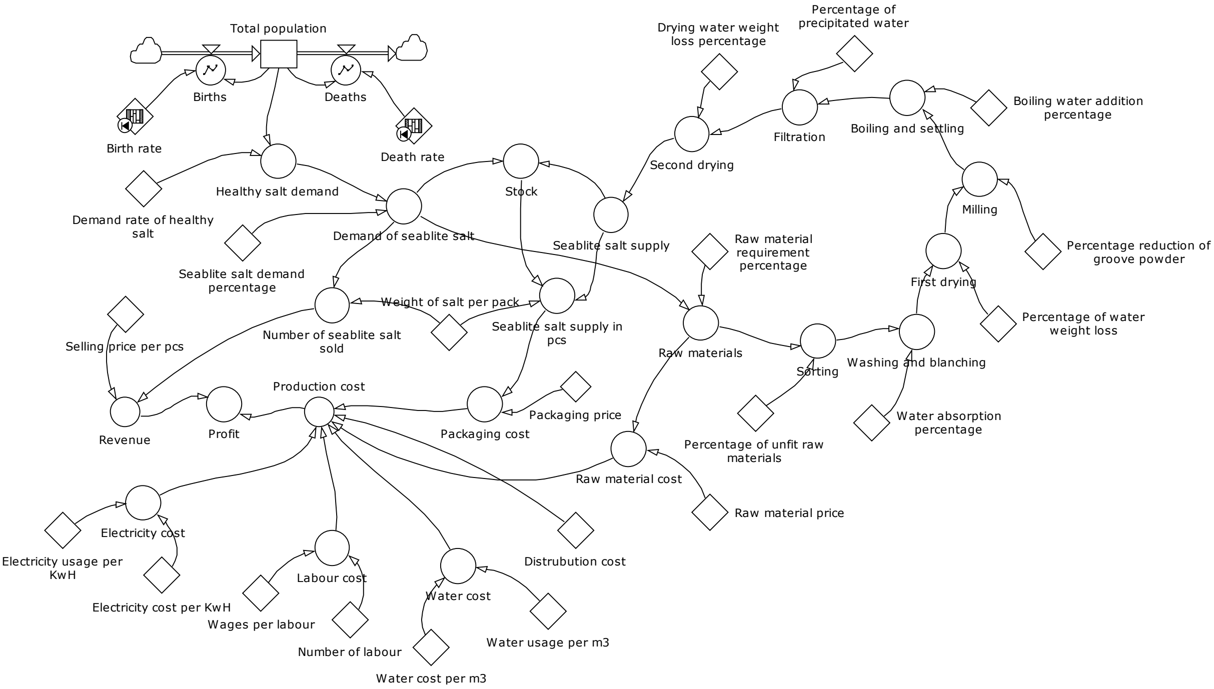

Fig. 2. Stock flow diagram of farmer revenue

4.2.2. Supply of seablite salt sub-model

The production sub-model represented Seablite salt production which was required to meet demand. The variable or element that had the most influence on the production sub-model was raw material. The amount of salt produced was influenced by demand and raw material required. Seablite salt production process's mass balance also influenced the sub-model. Each step in the production process was influenced by the amount of raw material used (input).

4.2.3. Production cost sub-model

Production cost sub-model comprised several variables or influential elements including raw material, labor, electricity, water, distribution, and packaging costs. The cost of raw materials was the product of the number of seablite plants used with the price of fresh Seablite plants per kg. Electricity, water, and distribution costs were calculated based on the amount used multiplied by the price provisions of PDAM and PLN for the industry. Labor costs were calculated based on the number of workers and wages. Determination of wages was calculated based on working hours per day. Additionally, packaging costs were calculated from the price of the type of packaging and labeling for each Seablite salt in packaged form.

4.2.4. Revenue of farmer sub-model

Revenue sub-model was influenced by the price and quantity demanded. The price was assumed to be the market price of similar salt products at IDR 50,000 per package. Each package of Seablite salt weighed 250 grams. Revenue was influenced by demand for Seablite salt that could be fulfilled. Revenue and profit affected each other where profits increased when revenue rose. Additionally, production costs affected the amount of profit earned. Higher production costs led to smaller profits obtained while the production cost increased when the amount of salt production increased.

4.3. Identification of variables

Identification of variables was performed through interviews, observation, and literature as well as divided based on the model. Error! Not a valid bookmark self-reference. showed the variables in revenue farmer assessment of Seablite salt production.

Tab. 1. The variables in revenue farmers' seablite (suaeda maritima) salt production assessment.

No	Variable	Type	Unit
1	Raw material	Auxiliary	kg/year
2	Weight of Seablite salt per pack	Constant	0.25 Kg
3	Water requirement	Constant	100 per $meter^3$
4	Electricity requirement	Constant	1,123 per kWh
5	Water cost	Auxiliary	IDR/year
6	Water cost per cubic	Auxiliary	IDR 3,700 /year
7	Raw material cost	Auxiliary	IDR/year
8	Distribution cost	Auxiliary	IDR 6,000,000 /year
9	Packaging cost	Auxiliary	IDR/year
10	Electricity cost	Auxiliary	IDR/year
11	Electricity cost per kWh	Constant	IDR 1,115 /year
12	Production cost	Auxiliary	IDR/year
13	Labor cost	Auxiliary	IDR/year
14	Filtration	Auxiliary	IDR/year
15	Raw material price	Constant	IDR 17,000 /kg
16	Selling price per pcs	Constant	IDR 50,000
17	Packaging price	Constant	IDR 1,500
18	Quantity of Seablite salt sold (pack)	Auxiliary	Per year
19	Number of workers	Constant	15
20	Total Population	Stock	270,203,900
21	Total production of salt Seablites	Auxiliary	kg/year
22	Total production of salt Seablites in pcs	Auxiliary	Per year
23	Births	Rate	Person/year
24	Deaths	Rate	Person/year
25	Profit	Auxiliary	IDR/year
26	Birth rate	Constant	1.707 %
27	Death rate	Constant	0.474 %
28	Healthy salt demand rate	Constant	0.00012 kg/person

No	Variable	Type	Unit
29	Washing and blanching	Auxiliary	kg/year
30	Revenue	Auxiliary	IDR/year
31	Second drying	Auxiliary	Kg/year
33	First drying	Auxiliary	Kg/year
34	Milling	Auxiliary	Kg/year
35	Boiling and settling	Auxiliary	Kg/year
36	Demand for flow salt	Auxiliary	Kg/year
37	Healthy salt demand	Auxiliary	Kg/year
38	Percentage of precipitated water	Constant	42%
39	Percentage of unfit raw materials	Constant	2 %
40	Percentage of raw material requirement	Constant	1,000 %
41	Boiling water addition percentage	Constant	100 %
42	Percentage reduction of Seablite powder	Constant	1 %
43	Percentage of water weight loss	Constant	82%
44	Drying water weight loss percentage	Constant	52%
45	Water absorption percentage	Constant	3 %
46	Seablite salt demand percentage	Constant	10 %
47	Sorting	Auxiliary	Kg/year
48	Stock	Auxiliary	Kg/year
49	Wage per worker	Constant	IDR 8,400,000) /year

4.4. Model validation

Model validation was carried out to test when the model represented the actual state of the study object. System validation was performed by paying attention to MAPE value where model validation with statistics figure less than 5% was more precise and between 5% - 10% was appropriate [69,70]. The results of verification and validation of salt flow production model were carried out on the total population with an average MAPE of 0.242. Similarly, the average value of MAPE on the amount of Seablite salt demand and supply were 0.204 and 0.398 respectively. Based on these criteria, the average was found to be less than 5% allowing the model to be accepted. The model represented the actual conditions of the population sub-model and could be used to determine the pattern of salt production. The table of MAPE test results was presented in Tab 2.

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Tab. 2. MAPE result test

	Total Population (person)		Demand of Seablite Salt		Supply of Seablite Salt	
	Simulation Data	Actual Data	Simulation Data	Actual Data	Simulation Data	Actual Data
2020	270,202,923	270,203,900	6,214.69	6,241.25	6,224.29	6,253.56
2021	273,535,514	272,682,500	6,291.32	6,299.52	6,301.03	6,285.63
2022	276,908,207	275,773,800	6,368.89	6,372.43	6,378.73	6,348.23
MAPE (%)	0.242		0.204		0.398	

5. Simulation Model Based on Scenario

Scenario development was carried out to predict potential outcomes by adding new parameters or changing the existing structure. There were three scenarios in this simulation including moderate, optimistic, and pessimistic.

Simulation model represented a future situation with all conditions remaining the same as the current (moderate scenario). This model based on actual conditions in Seablite salt production explained demand variables and raw material costs by current conditions. The price of raw materials in this scenario was IDR 17,000 per kg. Therefore, moderate scenario of each sub-model included (1) demand and supply with demand rate for Seablite salt of 0.00023 kg/individual, and (2) the production cost and revenue.

Optimistic scenario described demand for Seablite salt and raw material costs increasing from current conditions. This scenario explained the variables influencing salt demand production system when there was an increase in one or more variables. Four scenarios were considered namely (1) an increase in demand rate with fixed raw material prices, (2) constant demand for Seablite salt with a 2.94% increase in raw material prices, (3) increased demand for Seablite salt with a 2.94% decrease in raw material prices, and (4) increased demand for Seablite salt with a 2.94% increase in raw material prices.

Pessimistic scenario depicted a condition where demand for raw material prices fell from the current level. Similar to optimistic, pessimistic scenario affected the amount of salt produced, production costs, and revenue. It consisted of four scenarios namely (1) a 50% decrease in demand for Seablite salt with the price of raw materials remaining at IDR 17,000, (2) constant demand rate with a 29.41% decrease in raw material prices to IDR 12,000, (3) a 50% decrease in demand rate with a 2.94% increase in raw material prices, and (4) a 50% decrease in demand with a 29.41% decrease in raw material prices. In this condition, demand for Seablite salt fell by 0.00021, and the price of raw materials fell to IDR 12,000 per kg.

Simulation results using the comparison between several scenarios and the amount of revenue were observed in Figure 3. Consequently, there were 9 scenarios which included the following:

Scenario 1: Moderate scenario.

Scenario 2: Optimistic scenario (increased demand for Seablite salt and a 2.94% rise in raw material prices).

Scenario 3: Optimistic scenario (constant demand for Seablite salt while raw material prices increased by 2.94%).

Scenario 4: Optimistic scenario (demand for Seablite salt increased with raw material prices decreasing by 2.94%).

Scenario 5: Optimistic scenario (increase in demand for Seablite salt and a 2.94% rise in raw material prices).

Scenario 6: Pessimistic scenario (demand for seablite salt decreased by 50% with the price of raw materials remaining at IDR 17,000).

Scenario 7: Pessimistic scenario (demand rate for Seablite salt remained while the price of raw materials decreased by 29.41% or by IDR 12,000).

Scenario 8: Pessimistic scenario (demand rate for Seablite salt decreased by 50% with the price of raw materials increasing by 2.94%).

Scenario 9: Pessimistic scenario (demand for Seablite salt decreased by 50% and the price of raw materials decreased by 29.41%).

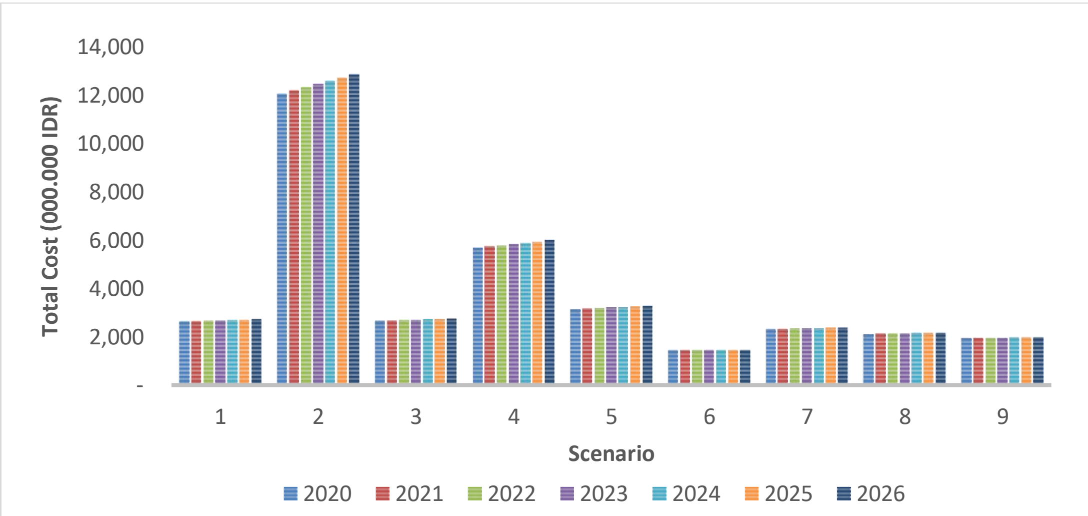

Fig. 3. Total revenue farmer based on the simulation results of each scenario

Based on the projection results of the amount of revenue and production costs using system dynamics method shown in fig 3**,** moderate scenario suggested that salt flow needs could be met. Revenue of farmers arose alongside the rise in salt sales which correlated with the increasing production costs. In optimistic scenario, it was found that salt demand until 2026 could be met. The increase in the price of raw materials affected production costs, allowing revenue earned by company to not cover production costs. In this scenario, farmers began to benefit because the total revenue was higher than production costs. High production costs were due to Seablite salt producing minimal crops, requiring significant raw materials to produce large amounts of salt. Profits could be obtained when demand increased to 0.00105 kg/individual, and the price of raw materials decreased by 2.94% to IDR 14,000. When demand per inhabitant was less than 0.00105 kg/individual, farmers would experience a loss which necessitated a vigorous marketing strategy. In pessimistic scenario, farmers experienced losses because production costs were very high compared to the income earned.

The managerial implications of implementing system dynamics method on the process of Seablite salt production were identified. This included the government facilitating the industrialization by streamlining the permit application process, expanding the amount of land available for planting, providing coastal communities with training in Seablite salt construction, and securing financial support from financial institutions as essential capital for seablite salt industry.

6. Conclusion

In conclusion, this study found optimistic scenario to be the best based on the results of modeling and projections in the publication of product productivity analysis of Seablite salt with system dynamics method. In this scenario, the amount of salt demand could be met where demand for Seablite salt increased by 0.00105 kg/individual while the price of raw materials decreased by 2.94%. The profits obtained from the projection results had the highest value of IDR 369,193,000. Efforts to increase farmer revenue should focus on improving marketing strategies. Farmers could also reduce production costs when cooperating with flow crop producers.

Future publications should include raw material and Seablite salt inventory sub-model, as well as healthier salt competitor. The seasonality of plant conditions necessitated the employment of raw material supply sub-model.

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