Optimization of Durian Supply Chain with Dynamic System Simulation

Nurhayati Sembiring, Ryan Ivanro Polinezer Sipayung
Industrial Engineering, Faculty of Engineering,
Universitas Sumatera Utara
nurhayatipandia68@usu.ac.id , ryansipayung@students.usu.ac.id

***Abstract*—Durian supply chain is affected by some variables such as producers, suppliers and consumers. This supply chain system must be analyzed deeply to get the optimum value to solve problem that have occurred so far related with economic, social and environmental aspect. This research begins by developing the primary model of supply chain of durian and find the problem variables. Then the system analysis is done through modeling and simulation of durian supply chains using anylogic software. The results show that the durian industrial system in North Sumatra is cross-sectoral because it is related to several related relationships. Optimization is carried out with a supply chain behavior prediction system in the next 10 years seen from social, economic, and environmental aspects. After increasing productivity from 0.72% by 1.69%, the use of chemical-based fertilizers is 104.952 tons / year in the following 10 years. In addition to the economic aspect, the increase in farmer profits to Rp. 2,475,010,917, -, adding labor to 250,340 people / year.**

Keywords—Supply Chain, Dynamic System Simulation, AnyLogic Software

I. INTRODUCTION

One of the fruits with a fairly good economic prospect in North Sumatra is Durian. North Sumatra's people, are very fond of this fruit, so that the increase in durian market demand has increased greatly in recent years and also the prices [1]. Besides, the price increase was triggered by the stagnant supply of durian production, while demand continued to rise. Durian fruit with good quality is on the market around Rp. 30,000 / kg while low quality is in the price range of Rp. 15,000 / kg. The low supply of durian production certainly makes this the main core of this durian supply chain problem, so it is necessary to optimize the durian supply chain from upstream to downstream components.

Much research has been carried out on increasing durian production, efforts such as optimizing planting areas, selecting superior seeds, treatment through fertilizers and other chemicals, have been carried out but limited by time, cost and the other problem. While, the use of simulation methods, in this case, is still small, on the other side, simulation methods have many advantages that can overcome these problems. So through this paper, we can overcome the problem of considerable time and cost with simulation.

Simulation is a knowledge that studies the real system model by using numerical valuation by software to imitate the characteristics and operation of a real system [2]. In this case the simulation will model a system consisting of a collection of elements interacting to meet certain objectives [3],[4]. A model must be able to reflect a system in a valid and detailed, but still simple because it is a simplification of a real system [5]. In general, dynamic systems are modeling that can analyze a system in a complex manner and are widely used as a method for prediction systems because it can produce better predictions in both short, medium, and long term trends [6],[7]. Dynamic systems can identify variables that are factors that influence the system so that the system has complex dynamics [6],[7]. Dynamic systems begin by defining the problem of a real system with related variables [8],[9]. Usually poured into the concept of Causal Loop Diagram then modeled in identifying stock or independent accumulation in the form of flow [9].

The Supply Chain consists of activities providing basic raw materials, then converting raw materials into semi-finished products or final products, as well as distribution or delivery to consumers (logistics) [10],[11]. This study makes the durian supply chain in North Sumatra a variable that is a factor that influences dynamic systems. Supply chains are consist of components that interact with each other, it is this interaction that represents the chain strands so that all of these components will make the system complex [10],[17]. Ni Putu et al. the research identified that the number of plants, labor (HOK), fertilizer use, plant age, and Lilis et al. land extension and conversion are factors that influence crop production [12],[13]. Household production and consumption have a big influence on supply, industrial income, and income in terms of the supplier sub-system [13]. The purpose of this study is to (1) determine the factors and variables that affect the durian fruit supply chain, (2) analyze the availability of durian fruit, (3) make alternative policy recommendations that can be done to meet the needs of durian fruit in North Sumatra Province.

II. RESEARCH METHODOLOGY

This study is started by identifying the entity's behavior in the durian supply chain component in North Sumatra. Then build a causal loop model and build a mathematical formulation of each component that becomes the supply chain variable that will be converted into a dynamic system.

A. Identification of durian supply chain components

The durian supply system in this study will be divided into three subsystems, that is the consumer subsystem, the producer subsystem, and the supplier sub-system. The components will be built as a basis for modeling the system.

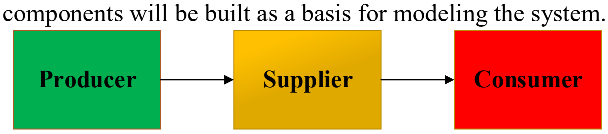

Fig. 1. Durian supply order.

1) *Producer Subsystem*

The durian producer sub-model is affected by variables : the area of planting, convertion of land (convertion), expansion of planting area (extensification), agroecosystem, number of working days, harvested area, and household income. In addition to the variables required a variety of constants that become parameters that facilitate modification if there is a change in the model according to real conditions. The constants in question are household income of durian farmers, pesticides, working day per hectare, percentage increase in planting area (extensification/year), land convertion percentage (conversion/year) and durian productivity.

2) *Supplier Subsystem*

The durian supplier sub-system is afftected by variables including durian production, the consumption of household, the consumption of durians industrial, durians industrial income, household income and total consumption, then there is the durian industry as the main entity that processes the results of durian production and then distributes it to consumers. The constants in the supplier sub-system are the price of durian per kilogram and the durian industry. Activities carried out by durian agro-industry such as durian production activities become processed foods made from durian and distribute them to consumers.

3) *Consumer Subsystem*

Consumer sub-system is strongly affected by how people's behavior on consuming durian. In this case, the people who consume durian are the people of North Sumatra. By this dynamic model, we can find out how the dynamics of durian demand and consumption are based on projected population growth. This certainly forms a new relationship between population growth rates and population death rates. In this case, the population will increased by the growth rate, whereas the population will decrease by the increases of the population death rates.

Based on the consumption demand sub-model, it can be seen that consumption patterns are based on population growth and how much the average demand for durian is consumed. Then the equalization value is converted in kg/capita/year. In this case, we will need a variable (constant) which is the parameter of durian consumption level, through this parameter, we will input the average value of durian consumption according to the real conditions to determine the durian consumption demand. Durian consumptions levels will then have the effect of consumption on the number of durian consumption. If the consumption of durian per capita increases, the amount of durian needed will also increase. This connection will be translated into a flow chart (stock and flow) with anylogic software.

B. Modeling The durian supply chain components

1) *Causal Loop*

A positive relationship if the value of an element experiences an increase resulting in an increase in the value of other elements, or if the value of an element decreases will cause the value of other elements to decrease. Conversely a negative causal relationship between one element with another element occurs if an increase in the value of a particular element will cause the value of other elements to go down or contrarily.

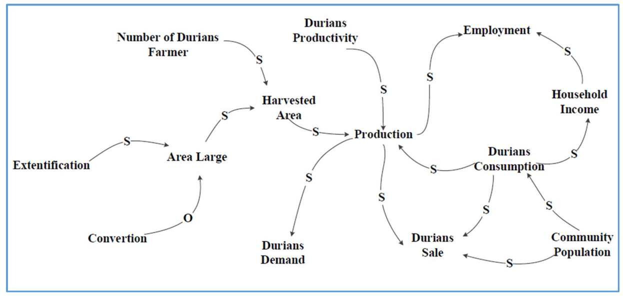

Fig. 2. Causal loop conjecture of durians supply.

2) *Modeling the Dynamic System Formulation*

The model is generally formulated based on assumptions. Assumptions are the rationale that is generally used to explain a phenomenon and its truth has been believed. Some basic assumptions are used in making the durian supply chain dynamic model, including: the average harvest age is 5.5 years durian, durian productivity in North Sumatra 33.73%, population growth rate is 0.011% and mortality rate is 0.007%, total work force per hectare of 190 TWK durian, annual use of fertilizer 0,843 kg / ha, the average price of Durian is Rp. 22,000 / kg,transfer of plantation land functions 0.11% / year and 0.21% / year extensification rate, and durian supply in the previous year (2019) 91766 tons. The formulation is based on the table I.

TABLE I. SOME OF PRODUCER SUBSYSTEM RELATIONSHIP FORMULATION

Variable in Causal Loop	**Model Building**	**Formulation**	**Unit**
Production	Stock	Production= [(Industries Consumption + ConsumptionRT) ; (HarvestedArea *Productivity)]	Ton/year
Harvested Area	Variable	HarvestedArea = AreaLarge/ (PlantingArea * 0.12 * GrowthTime)	Ha/Year
Agroecosystem	Variable	Agroecosystem = AreaLarge * Fertilizer	Kgha/Year
Growth Time	Parameters	5.5	Year
Area Large	Parameters	3036	Ha
Extentification Rate	Parameters	0.0021	Ha/Year
Convertion Rate	Parameters	0.0011	Ha/Year
Durians Price	Parameters	22.000	Rupiahs/Kg

The Supply will be built as stock, Industries Income and the Income Total will be the variable. The supplier subsystem relationship formulation is in the following Table.

TABLE II. SOME OF SUPPLIER SUBSYSTEM RELATIONSHIP FORMULATION

Variable in Causal Loop	Model Building	Formulation	Unit
Supply	Stock	Supply = (Production - ConsumptionRT)	Ton
Industries Income	Variable	IndustriesIncome = IndustriesConsumption * DuriansPriceperKg	Rupiahs /Ton
Income Total	Variable	IncomeTotal = ConsumerIncome + IndustriesIncome	Rupiahs / Year

Population will be built as stock, the consumption total, durians cosumption, and the population growth will be built as variable. Formulation of the consumer subsystem relationship will be explained in the Table III.

TABEL III. SOME OF CONSUMER SUBSYSTEM RELATIONSHIP FORMULATION

Variable in Causal Loop	Model Building	Formulation	Unit
Consumption Total	Variable	TotalConsumption = IndustriesConsumption + ConsumptionRT	Ton / Year
Durians Consumption	Variable	DuriansConsumption = Population * ConsumptionRate	Ton / Year
Population	Stock	Population = 267000000 + PopulationGrowth - PopulationDeath	Person
Population Growth	Variable	populationGrowth = 267000000 - (267000000 * PopulationGrowthRate)	Person

The formula will be entered into the initial value column in the properties window of AnyLogic Software, by previously clicking on the component to be linked.

C. System Model and Dynamic Simulation

Relationships between the entities in a system will modeled with anylogic software [14], [15]. The durian supply chain subsystem will be modeled as Stock, the factors affecting the subsystem will be modeled as dynamic variables, the formulation of the relationship between variables to the subsystem will be modeled as flow, and constants will be modeled as parameters, and will be connected by Loop. The simulation model and result will shown in the section III.

III. RESULTS AND DISCUSSION

The logic framework of the dynamic system modelling in AnyLogic software is shown in the Fig 3 and Fig 4 show how the simulation is running on AnyLogic Software.

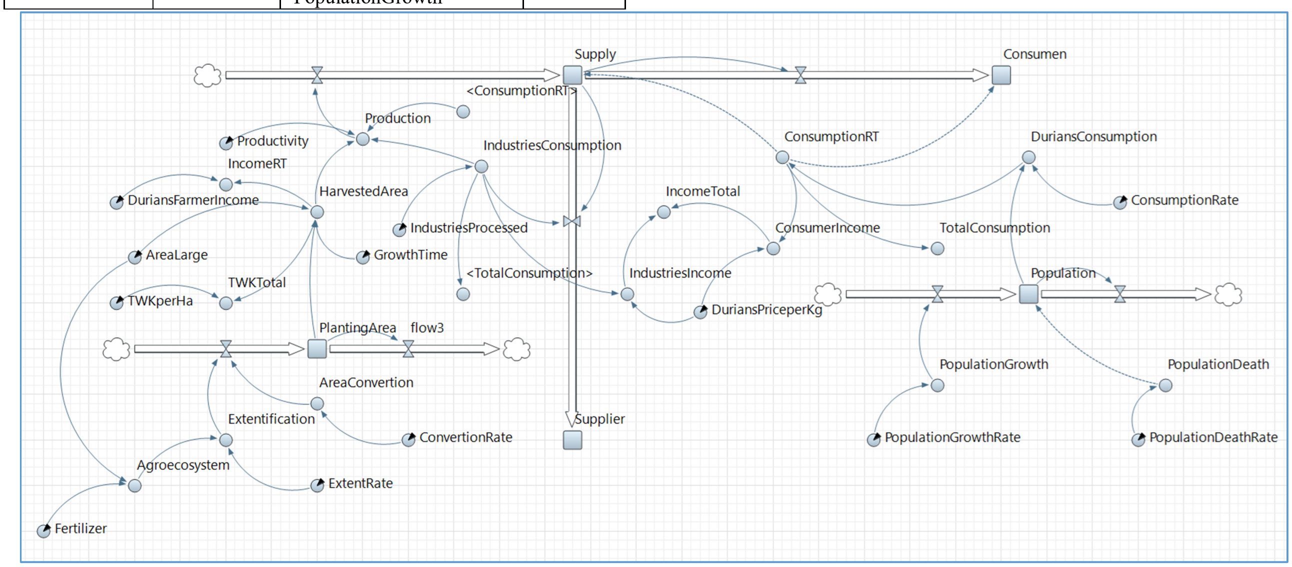

Fig. 3. Logic framework of the dynamic system model on AnyLogic Software.

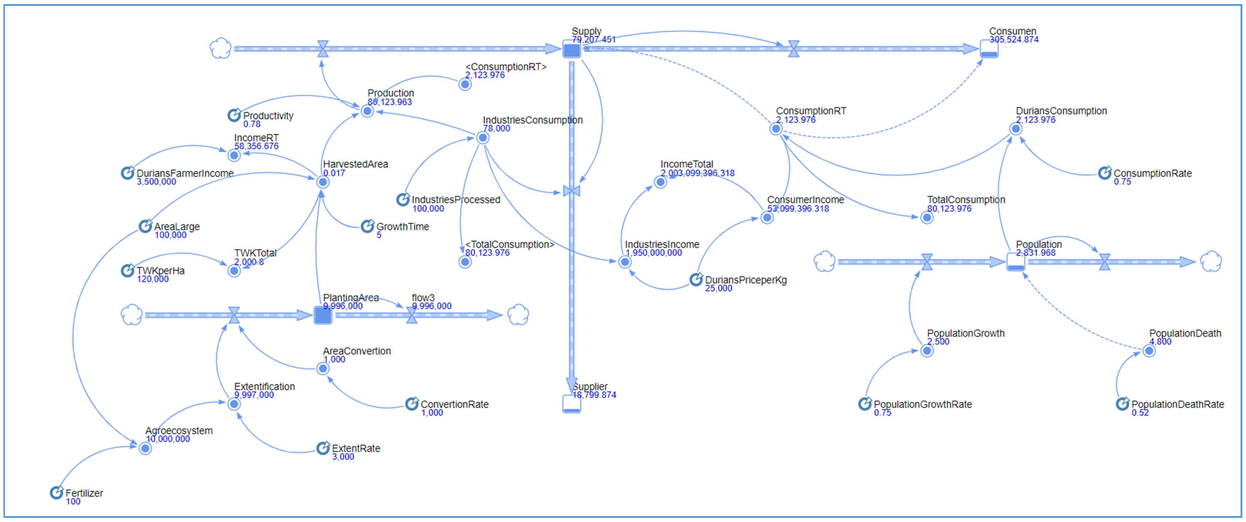

Fig. 4. Dynamic simulation on AnyLogic Software.

A. Validation and Verification Model

In this section, the simulation data will be compared with data from the real system to validate the model. Validation is carried out on the actual data, namely durian harvested area and total production in 2014 - 2018. Based on the criteria for MAPE value [16]:

$$MAPE = \frac{Y-Y'}{Y} \times 100\% \quad (1)$$

TABEL IV. DATA EXIST AND DATA SIMULATION HARVESTED AREA DURIAN

Year	Harvested Area (Ha)	
	Data Exist	**Data Simulation**
2014	4.144	4.767
2015	3.688	3.741
2016	2.856	3.108
2017	4.708	4.793
2018	4.512	4.318

After a system simulation, the data obtained as in the following Table :

TABEL V. DATA EXIST AND DATA SIMULATION PRODUCTION DURIAN

Year	Production (Ton/Ha)	
	Data Exist	**Data Simulation**
2014	80.441	81.004
2015	65.530	64.791
2016	74.811	73.229
2017	64.659	66.473
2018	82.872	84.980

MAPE (Mean Absolute Percentage error) value of 4.40% was obtained for the harvested area data and 1.86% for the durian production data. It was concluded that the model is very appropriate and acceptable.

B. Scenario Analysis for The Next Ten Years

Due to the simulation results are correct, an analysis is carried out to find out the state of the system in the next 10 years.

1) Scenario System Next 10 Year Without Optimization

This scenario is assumed to be a simulation without land optimization (extensification), expansion of the planting area (extensification) and increased durian production. It can be seen in the Fig 5:

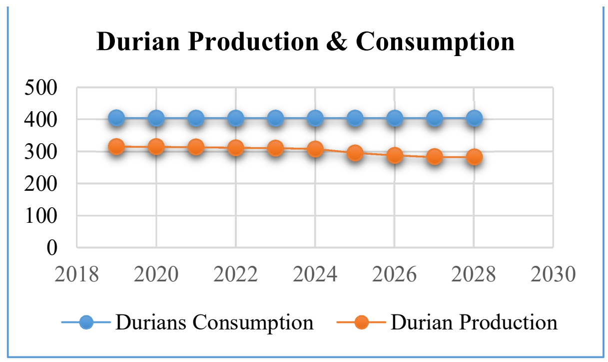

Fig. 5. Scenario of durian production and durian consumption without optimization.

Simulation results of durian production have decreased in the range 2019-2028, while durian consumption remains at the same inclined level. It was found that durian production was still less than durian consumption.

a) Analyzing The Impact For The Social aspects

The social aspect considered is the availability of durian supply to meet the availability of durian consumption demand. Then see the comparison of the number of durian production with the number of requests. The social aspects analyzed were Total Working Day (TWD), and the following results were obtained. With the 2019 simulation results obtained by 209100 and continued to decline until the year 2028 to 184100.

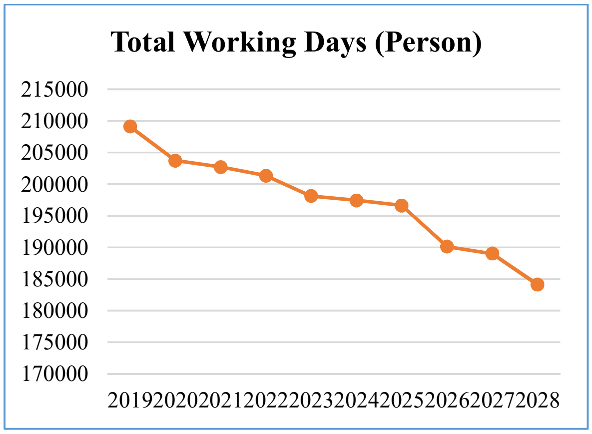

Fig. 6. Total working day without optimization.

b) Analyzing The Impact For The Economic Aspects

Durian farmers' income is derived from the sale of durian fruit, both income from overseas sales and domestic income. Durian sales revenue tends to decrease along with the stagnation of durian production. Based on 2019 the simulation results obtained were 2,094 million rupiahs and continued to decline until 2028 to 1,997 million rupiahs. the decrease in household income was significantly affected by the limited availability of durian, resulting in a decline of up to 10 years

c) Analyzing The Impact For The Environmental Aspects

In pursuing the fulfillment of durian demand, it is necessary to do an indication in the expansion of durian planting areas. So that the durian planting area increases the more the use of fertilizer increases. Increasing the use of fertilizer also increases the chance of environmental damage. The accumulation of chemical compounds is proven to disrupt ecosystems starting from the food chain system to cause cancer and health problems in living things. A decrease in fertilizer using also be seen from the simulation results. with a fixed area of harvest while durian productivity decreases with increasing durian's age.

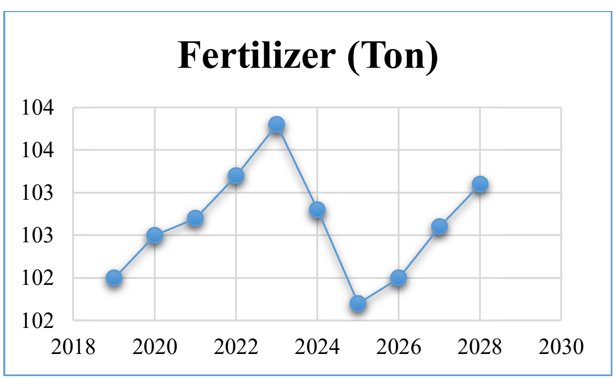

Fig. 7. Fertilizer used in next 10 year without optimization.

2) Scenario System Next 10 Year With Optimization

Increasing the durian productivity from 0.72 tons / ha to 1.69 tons / ha is expected to be able to meet the needs of durian in North Sumatra. Fig 8 is an illustration of the results of the optimization of the system in the next 10 years through increased productivity.

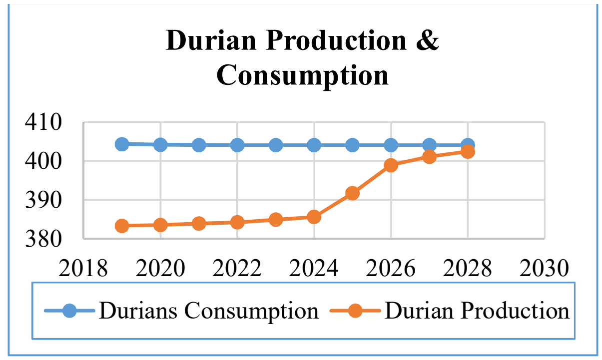

Fig. 8. Scenario of durian production and durian consumption with optimization.

After changing the optimization value of productivity in the supply system, it appears that an increase in durian production and increase the TWD, Household Income and the Fertilizer that indicated by an increasing graph. Then an analysis of the three aspects is as the fig. 9, Fig. 10, and Fig. 11.

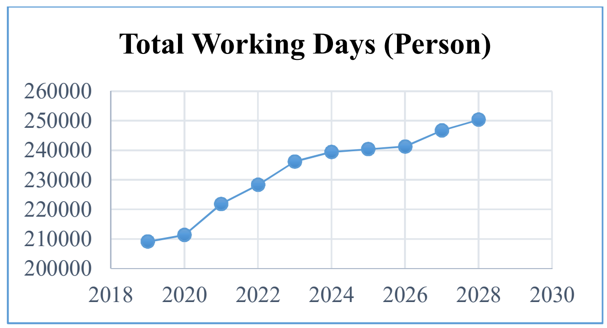

Fig. 9. Total working day with optimization.

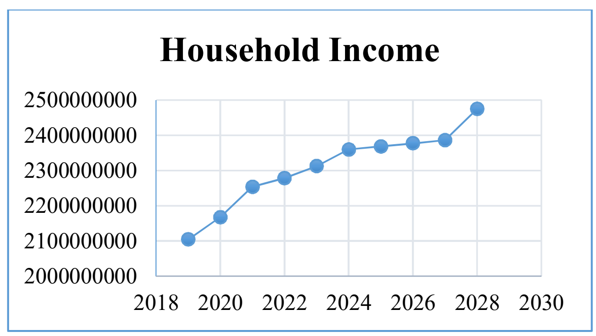

Fig. 10. Household Income with optimization.

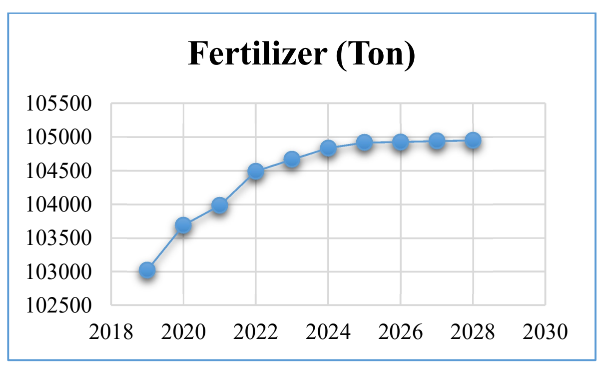

Fig. 11. Fertilizer used in next 10 year with optimization.

In terms of social aspects, the number of working days increased linearly to 2028 with a value of 250,340 people/day. In terms of economic aspects, the increase was marked by an increase in linear income for the next ten years with a value of Rp. 2,475,010,917. To the environmental aspects, namely the total use of fertilizers with a total of 104,952 tons/year.

IV. CONCLUSION

Optimization through dynamic system simulations is very effective and makes it easy for us to obtain information. Dynamic systems are clearly able to tell us how the relationship of each sub-system, to how the variables of each sub-system affect the sub-system itself. North Sumatra's durian industrial system consists of several sub-systems, including the producer, supplier, and consumption sub-systems. Each subsystem consists of elements or elements that are more specific and are strongly influenced by time development so that the North Sumatra durian industrial system is dynamic.

Producer subsystem is affected by some variables such as area of planting area, agroecosystem, number of working days, harvested area, land conversion (conversion), expansion of planting area (extensification), and household income. The supplier sub-system is affected by variables including durian production, industrial income, household consumption, total consumption, industrial consumption, and household income. Consumer subsystem, durian consumption is affected by how people's behavior in consuming durian. In the sub-model of consumption needs, it can be seen that the state of the population greatly affected by the durian consumption demand.

Durian supply chain system in North Sumatra province for the next 10 years seen from the social, economic, and environmental aspects using a scenario of increasing durian productivity from 0.72 tons/Ha to 1.69 tons/Ha. The increase in the use of fertilizers made from chemicals to 104.95 ton in the next 10 years. From the economic aspect, the linear profit increase of farmers in a linear manner is Rp. 2,475,010,917,-, then opened the opportunity to increase employment to 250,340 people/year.

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