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Development of Environmentally and Economically Patchouli Cultivation Using *System Dynamic Analysis* in Aceh Jaya Regency, Indonesia

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ABSTRACT
Patchouli oil is one of the Indonesian essential commodities accounting for approximately 95 % of the world market. Patchouli farming requires generous support of inputs. This situation puts traditional Patchouli farmers in a dilemma between boosting the quantity or protecting the environment. This study aims to provide a framework to examine the impact of reducing shifting cultivation and disease using a system dynamics model. A causal loop and stock-flow diagram of patchouli cultivation are illustrated qualitatively. Using surveyed data from the Patchouli producing region in Aceh Jaya subdistrict of Aceh Province-Indonesia, this study identifies the actions needed as input to develop patchouli cultivation that is environmentally and economically viable. The study shows that the selection of varieties, cropping patterns, adding nutrients through fertilization, paying attention to plant health are essential to improve the patchouly cultivation system.

Keywords: *System Dynamics, Sustainable Farming, Framework, Shifting Cultivation, Patchouli*

1. INTRODUCTION

Patchouli is an essential oil-producing plant known as Patchouli oil. Patchouli (Pogostemon Cablin Benth) is widely planted in Aceh Province (Mangun et al., 2012) because this variety produces high quality and oil quantity. This variety is associated with high Patchouli alcohol (PA) (around 30%). Patchouli oil can be a profitable business that deserves to be developed. Patchouli oil is a fixator in the perfume/fragrance, cosmetic, pharmaceutical, and aromatherapy industries (Ermaya, 2019).

Other materials have not substituted the ability to replace Patchouli as a fixator to date, so the uniqueness of Patchouli is a real selling point. Indonesia, especially the Province of Aceh, has an agronomic wealth that strongly supports the development of Patchouli. Back to the Dutch East Indies government, Aceh Province has been known as a central production of Patchouli in Indonesia. At the lowlands, the oil content is higher, but the patchouli alcohol is low. On the contrary, the Patchouli Alcohol (PA) is found higher at the highlands (Nuryani et al., 2005).

Indonesia is one of the largest suppliers of patchouli oil in Asia and a significant producer of patchouli oil in the world, controlling around 95% of the world market (Directorate General of Estate, 2020). Patchouli, from cultivation to processing, is relatively simple to manage. Technically, this simple cultivation should increase the motivation to develop. However, the current condition of patchouli cultivation is neglected. The present figures show that Indonesia's patchouli production has tended to be unstable and declining (Statistics Indonesia, 2015). In Aceh, the Patchouli cultivation area was 2,502 Ha in 2015 and decreased to 1,209 Ha in 2018. Aceh produced 646 tons of Patchouli in 2015 and, it fell to 177 tons in 2018 (Indonesian Patchouli Statistics, 2020).

It is necessary to re-examine the issues that affect the decline in farmers' interest in cultivating the Patchouli. The solutions are needed to promote patchouli cultivation while increasing yields in terms of quality and effectiveness. Price volatility has been the main

factor of the decreasing interest of the Pachouli farming in Aceh. However, by improving the cultivation process to distillation, it may succeed in suppressing price fluctuations.

The condition of traditional Acehnese farmers with limited land with shifting cropping patterns makes patchouli farming seem complicated and neglected. It is expected that patchouli cultivation will be successful and profitable, and it will be more attractive to cultivate farmers. Methodologically, literature on the dynamic context that can visualize the relationship between the development in the upstream side and patchouli demand in the downstream is not widely available. The lack of dynamic context probably cause the dis-integration of each sectors in the pacthouli agro-industry system.

Jay Forester introduced System Dynamic in 1950, where the System Dynamics model is classified into a causal mathematical model. System dynamic is a method used to describe, model, and simulate a system dynamic in processes, information, boundaries, and strategies. Its model represents a real problem using mathematical language. One of the objectives of the System Dynamic is to obtain stability analysis. System Dynamic starts from assumptions that the behavior of the system then develops as its structure. The structure of the system needs to be changed to correct unwanted behavior. System Dynamics makes it possible to identify desired system changes and test them in a 'virtual laboratory' (Pruyt, 2013).

System dynamics is widely used in various fields of science and research. System Dynamics is also applied in multiple models to support development through the input of policy suggestions in decision-making and the development of strategies aimed at developing with the best scenario. The following are some studies using dynamic systems. Mala Rosa et al. (2019) provide the Stock Flow Diagram of paddy production provides output using the System Dynamics simulation model to increase paddy production for food security in Indonesia. Rahmayanti et al. (2019) describe the Stock-Flow Diagram of Patchouli consisting of plantations, farmers, collectors, exporters sections to conceptualize dynamic systems for agro-industry development. Aminuddin et al. (2014)provide a simulation of a dynamic model of the potato supply chain in the effort of national food security. Maulida et al. (2017) described the loop and stock-flow diagrams of maize in Indonesia.

ZThis study aims to identify the data needed as input in the formulation of development in Aceh Province. We used a System Dynamics model to evaluate the current conditions of Patchouli farmings and provide a basis to simulate the effective and efficient scenarios. This research was conducted by designing the Causal Loop Diagram (CLD) and the Stock Flow Diagram (SFD) of the Patchouli plantation section. Changes in ecological improvement and production are determined by the existing inputs and outputs, which concern the cause and effect that influence them.

2. METHODS

2.1. Study Area

This research is located in the Aceh Jaya Regency, Aceh Province of Indonesia. It has an area of approximately 387,272.36 Ha. The climate in Aceh Jaya district is suitable for Patchouli cultivation which has an altitude consisting of 0-100 to 2000 meters above sea level and a slope of 0-≥40%, which is flowed by large and small rivers. The research object focuses on patchouli farmers, especially in the planting process. We focus on the cultivation activities considering ecological factors.

2.2. System Dynamic Approach

The stages carried out in this research are:

- Surveys and interviews with patchouli farmers and stakeholders in Aceh Jaya
- Study of literature including the development of patchouli cultivation and System Dynamics
- Determine the factors that affect the patchouli cultivation process
- Design the Stock and Flow Diagram (mathematical relationship between related factors)
- Determine the input and output dynamics of the system.

Data collection was done by:

- Interviewing five farmers, two agricultural extension workers, 1 farmer group leader who are directly involved in Patchouli farming in Aceh Jaya Regency
- Identification data of the National Patchouli Plantation from the Statistics Agency

The description of the current patchouli farming activities and processes by Aceh Jaya Farmers is outlined in the Causal Loop Diagram (CLD). The design conditions are simulated that support the creation of a balanced ecology. Then, the description using inputs to support the cultivation and the projecting results is outlined in the Stock Flow Diagram.

3. RESULTS AND DISCUSSION

Patchouli cultivation in Aceh Jaya has been done traditionally, and we illustrate them in the Causal Loop Diagram as follows:

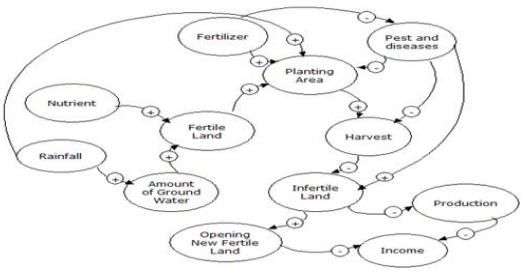

Figure 1. Pachouli Cultivation Current Condition Causal Loop

Figure 1 begins with selecting and determining fertile land for patchouli cultivation. The determination is still traditional without first knowing the nutrient content of the selected areas. Original areas are considered fertile and will be used as the selected cultivation land. Diseases generally attack plants, and no further anticipation is needed in this situation. Rotten plants are exterminated by pruning or uprooting and destroying them. The survived plants will be harvested. Generally, after two to three consecutive harvests, the existing land is considered no longer fertile. This is also marked by a decrease in the amount of production. The land is then abandoned for a while with the aim that natural processes will restore the fertility level.

The causal loop diagram shows that no action is needed to improve the condition of the land so that it remains in a fertile condition for re-cultivating the land. Farmers left the existing land and moved to new areas. These habits have impacts on the ecology, social and economy of Patchouli farming. Ecologically, the effect is increased land damage, land restoration takes time, and abandoned land becomes unproductive. Economically, the decline in land conditions also reduces production, so that it has an impact on farmers' income. The opening of new land also requires more costs. It is also socially related to land ownership status. Shifting cultivation causes farmers to wait and choose not to cultivate Patchouli temporarily.

The current condition of patchouli cultivation is considered un-environmentally friendly and has less economic value. Therefore, information related to patchouli cultivation and input from farmers as well as local leaders is needed. Cultivation system improvement requires supporting factors that restore the level of fertility in the form of technological intervention described in the following Causal Loop:

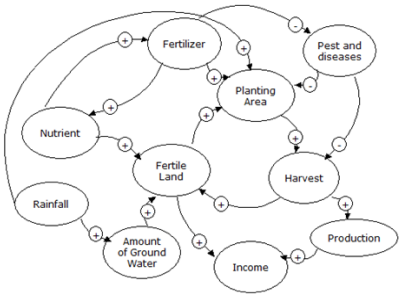

Figure 2. Pachouli Cultivation Planning Causal Loop

Figure 2. represents traditional cultivation, which leaves infertile soil after the cultivation process. The sustainable concept for patchouli cultivation needs to be developed so that land fertility may restore after the harvest process.

Calculation of inputs and detailed sequence of work steps are needed for improvement. Ensuring plants are in excellent and healthy condition is the key to successful cultivation. It will increase productivity, and so the income. After obtaining the expected revenue, it can be replanted and contribute to ecological stability.

The Causal Loop diagram of Pachouli cultivation planning provides the basis for reference of Stock Flow diagram as follows:

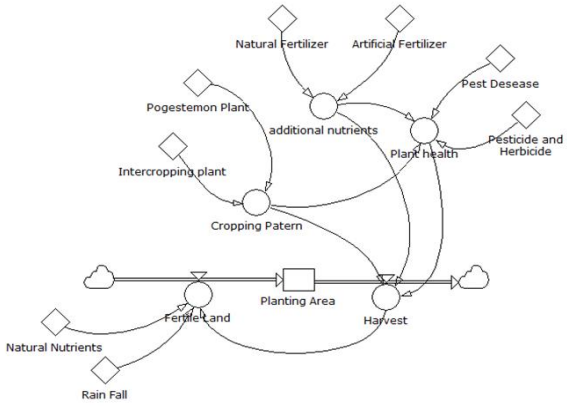

Figure 3. SFD of Pachouli Sustainable Cultivation

Determination of the formula based on SFD as follows:

Planting Area = Fertile Land = Harvest (1)

This will be realized if the factors during the cultivation process are measured and adequately resolved, namely:

Fertile Land = % Natural Nutrient + % Rainfall

$$\text{Cropping pattern} = \frac{\text{Intercropping Plant}}{\text{Variant Pogostemon Plant}}$$

Additional Nutrients = "Natural Nutrient" + Natural Fertilizer + Artificial Fertilizer

Plant Health = Nutrients + (Pest Disease after getting Pesticide and Herbicide)

Harvest Land = Cropping Pattern + Additional Nutrients + Plant Health

The objective of SFD is to identify the size of suitable areas according to the total area, and the fertility will be restored without reducing its area. The initial stage for the cultivation process is selecting cultivated land by calculating the nutrient availability. It also takes into account the weather since the rainy season is the most suitable to start planting the Patchouli. A comparison of the nutrient needed by Patchouli during the cultivation process is needed. From

the beginning, it is known the quantity of fertilizer is needed.

By knowing the fertilizer needs will facilitate the preparation process. Fertilizers may be chemical or natural fertilizers. This will also provide an overview so that farmers can prepare ahead of time.

The selection of cropping patterns is also essential. The cropping pattern provides input for nutrient exchange and acts as the natural breaker of pest chains and disease attacks. From the previous study, patchouli polyculture with other plants should be a good input while selecting the most suitable varieties for land, weather, and environmental conditions.

4. CONCLUSION

The development of Patchouli cultivation in Aceh Jaya Regency is considered potential. The condition of the land supports Patchouli to grow. The supporting inputs that are available. Socially, local communities are receptive to input, a reasonable basis for complementary technological interventions. All of these elements shall work together to support the establishment of sustainable patchouli cultivation.

Technological interventions are needed to supply a suitable growing environment for Patchouli. It may consist of the selection of varieties, cropping patterns, adding nutrients through fertilization, paying attention to plant health. All of these actions are needed to be adopted to achieve a profitable business.

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