

Diversification of Local Tubers through Optimization of Cocoa Farming in Supporting Sustainable Food Security

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Submission date: 04-Apr-2023 01:56AM (UTC+0700)

Submission ID: 2054868919

File name: cation_of_Local_Tubers_through_optimization_of_cocoa_farming.pdf (564.97K)

Word count: 4026

Character count: 21389

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2
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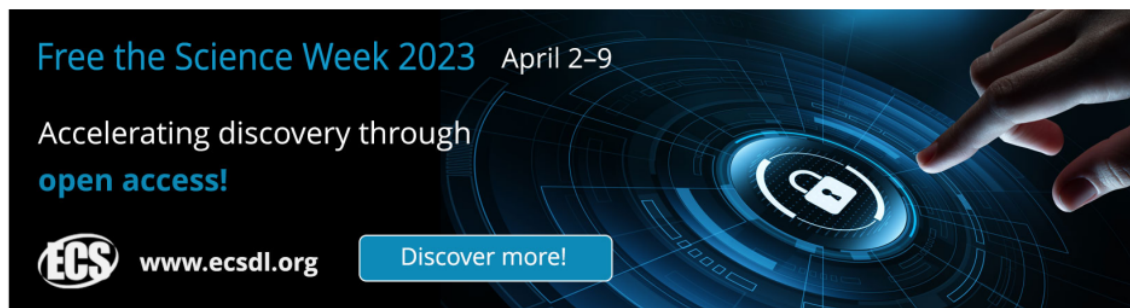
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Diversification of Local Tubers through Optimization of Cocoa Farming in Supporting Sustainable Food Security

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Abstract. The rate of world population growth gets faster every year, while on the other hand the land available for food production activities is increasingly limited. Efforts to increase income and food crop production by using cocoa farming to support national food security can be done by optimizing of land through crop diversification patterns by planting local tubers under cocoa farming. This research aims to analyze the optimization of land use, revenue and production costs. In addition, analyzing the nutritional content contained in each type of local tubers, namely sweet potato, cassava and taro. The research was conducted in the the buffer zone of Lore Lindu National Park (TNLL), Palolo District, Sigi Regency, Central Sulawesi Province, Indonesia. The results showed that the optimization of land use and revenue was obtained through the diversification pattern of sweet potato and cocoa. Optimization of the costs use occurs in the use of fertilizer production inputs. In addition, sweet potatoes have a higher calorific value, protein and fat compared to cassava and taro. However, the carbohydrate content of cassava is higher than that of sweet potato and taro.

1. Introduction

Indonesia has a **13** potential resource base spread in almost all regions, as the basis for efforts to strengthen and improve **food security at the national, regional and household levels** [1]. **The abundance of** available resources provides a great opportunity for this nation to develop food security independently [2]. These opportunities are related to the potential of natural resources to increase resource productivity in various ecosystems such as wetlands and dry lands with the support of appropriate technology based on the specific area of the local community as well as various local food sources to support community food security [3]. However, no matter how big the potential is, if there is no sustainable management effort, it will certainly not be able to provide maximum results. The fact shows that in recent years the issue of



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food sufficiency has become an important issue. This because the rate of world population growth gets faster every year, while on the other hand the land available for food production activities is increasingly limited [4].

Efforts to increase income and food crop production by utilizing cocoa farming to support national food security can be done by optimizing of land through crop diversification patterns by planting local tubers under cocoa farming [5]. All land has the potential to support human life, both rice fields, plantations and forest lands based on their use. The difference in land use depends on the carrying capacity of the land which is also different from one another. Optimization of farming is supported by land use patterns in an area/area of which productivity and stability depend on resource maintenance [6]. The pattern of land use carried out by farmers is the result of their limited resources allocation such as land, labor, pesticides, fertilizers and seeds to optimize income.

The pattern of land use in the form of crop diversification based on several previous researches is profitable from the economic aspect by minimizing the risk of lower income because it is not affected by fluctuations in market prices and relatively lower production costs. The results showed that the total product through the diversification pattern was much higher than the monoculture pattern. The failure of one crop type will be covered by the success of other crop types, minimizing the use of production inputs and optimizing income and competitiveness [7]. The results of other researches show that land use through crop diversification patterns by cassava and sweet potatoes has increased the amount of vacant land-cover in the monoculture cocoa cropping pattern. This can increase the infiltration process of surface runoff by 10-20% compared to without land cover vegetation [8]. Subsequent research concludes that diversification of local tuber crops with cocoa can accommodate the need to increase production and farm efficiency towards sustainable agriculture and preserve local wisdom [9].

Based on this, it is necessary to research the pattern of land diversification as a land use system that is acceptable to local farmers from the socio-economic aspect and supports sustainable food security in relation to food crops cultivated by subsistence farmers around the TNLL forest. Based on this, it is necessary to research the pattern of land diversification as a land use system that is acceptable to local farmers from the socio-economic aspect and supports sustainable food security in relation to food crops cultivated by subsistence farmers around the TNLL forest. This research aims to analyze the optimization of farm income through the diversification pattern of local root crops under cocoa farming based on the optimization of land area use, farm income and use of production inputs. The selection of local tubers is based on the nutritional value content as a supporter of food security in Sigi Regency, Central Sulawesi Province. Through the application of appropriate location-specific agricultural technology, land productivity can be used not only for one type of crop. With more than one type of plant, farmers around the forest can optimize their income and meet household food needs through the production of cultivated tubers [10].

2. Method

2.1. Research location and period

The research location was determined by a purposive sampling method with consideration of the limited number of farmers who cultivate local tubers on cocoa farming through crop diversification patterns. Respondent farmers were 30 people determined purposefully who were cocoa farmers around the buffer zone forest of TNLL, Palolo District, Sigi Regency, Central Sulawesi Province [11]. The research was conducted from August 2020 to February 2021.

2.2. Data collection and analysis

The research was conducted with qualitative and quantitative methods. Qualitative research data were collected from direct interviews with respondent farmers including the implementation of land management, the use of production inputs (seeds, fertilizers, insecticides and labor), the amount of production, prices, revenues and farm costs. While the nutritional content of tubers were obtained through the results of laboratory tests includes the content of calories, protein, fat and carbohydrates.

Optimization of farming with a diverse pattern of cocoa crop with local tubers is carried out quantitatively with the formulation of the Linear Programming model with the help of LINDO (Linear Interactive Discrete Optimizer) software, with the following mathematical model:

$$\text{maximize/minimize } Z = C_j X_j \tag{1}$$

Against the function constraints

$$\begin{aligned} a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \dots + a_{1n}X_n &\leq X_n \geq b_1 \\ a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + \dots + a_{2n}X_n &\leq X_n \geq b_2 \\ a_{m1}X_1 + a_{m2}X_2 + a_{m3}X_3 + \dots + a_{mn}X_n &\leq X_n \geq b_m \end{aligned}$$

Information :

- X-j : Decision variable of j
- C-j : Objective function parameter of j
- b-i : Constraint capacity of i
- a-i : Constraint function parameter of i for the decision variable of j
- i : 1, 2, 3, m
- j : 1, 2, 3, n

The model used to obtain the optimal level of income is a linear programming model [12]. The steps in using a linear program are as follows.

2.2.1. Determining decision variables

The decision variable shows the number of each type of food crop that should be produced by subsistence farmers in order to achieve optimal conditions, so that in the preparation of the linear program model several decision variables for each village can be formed as follows:

- X1 = Sweet Potato + Cocoa
- X2 = Cassava + Cocoa
- X3 = Taro + Cocoa

2.2.2. Determining the constraint function

Farm management faces various obstacles to achieve the goal (optimal income). In food crop farming, there are various constraint functions that will later become a condition for obtaining maximum income, in addition to land area, seeds, fertilizers, pesticides, and labor. The application of linear programming in this research, then formulated a linear programming model which is formulated as follows:

Maximize objective function (profit) $\text{Max } Z = \sum_{ij=1}^{17} C_{ij} X_{ij}$.

For-i is a group of local root crops (cassava, sweet potato and taro). Constraint function:

- Labor $\sum_{j=1}^{17} a_{ij} X_j = A_i$
- Seeds $\sum_{j=1}^{17} b_{ij} X_j = B_i$
- Fertilizers $\sum_{j=1}^{17} c_{ij} X_j = C_i$
- Pesticides $\sum_{j=1}^{17} d_{ij} X_j = D_i$

2.2.3. Determining the objective function

The main objective of optimization carried out by subsistence farmers is to maximize profits. The formulation of the objective function begins with finding information and processing it. The basic assumptions in linear programming (linear programming):

- Proportionality, this assumption means that the rise and fall of the goal value (Z) and the use of available resources or facilities will change proportionally with changes in the level of activity.

- Additivity, this assumption means that the goal value of each activity does not affect each other or in a linear program. It is assumed that the increase in the Z value caused by the increase in an activity can be added without affecting the Z value portion obtained from other activities.
- Divisibility, this assumption states that the output produced by each activity can be in the form of fractions, as well as the resulting Z value.
- Dual Prices, explains the magnitude of the optimum change in each unit of change in available resources as a constraint [13].

5

3. Results and discussion

3.1. Optimization of land-use

Previous researches have explained that land has a considerable influence on agricultural production, especially for rural farmers who are still traditional, where land area is still directly proportional to productivity. Vertical production zones can be optimized by selecting varieties with different nutritional requirements, so that they can produce maximum product in a limited area of land [14]. Combinations of plants can be selected from different families, for example tree species for shade as well as the highest level, then tall tuber plants (cassava), then tubers that propagate or plants with underground tubers. Based on the description above, it can be noted that land use has a significant impact on the productivity and ability of farmer households to optimize income and meet family food needs [15].

Farmers around the buffer zone forest TNLL optimize the area of cocoa through a diverse pattern. The results showed that optimal land use through a diversification pattern was achieved by increasing the land area between sweet potato and cocoa from 18.20 ha to 22.16 ha, taro and cocoa from 6.50 ha to 7.56 ha initially. Meanwhile, the land area for cassava and cocoa, which was originally only 10.75 ha, was reduced to 5.75 ha. This shows that the diversification pattern between sweet potato and cocoa is more profitable than taro with cocoa or cassava with cocoa, as shown in Table 1.

Table 1. Optimization of land-use.

Commodity	Initial (ha)	Optimal (ha)
Sweet potato and Cocoa	18.20	22.16
Cassava and Cocoa	10.75	5.73
Taro and Cocoa	6.50	7.56
Total	35.45	35.45

3.2. Optimization of Revenue

The acceptance by cocoa farmers based on the feasibility analysis of farming has not been able to properly support the life of the farmer's family because the average farmer has a farm area of 4 ha. Based on the result 5 of previous researches, it is shown that cocoa farming will support the livelihood of farmers with a land area of 7 ha. Thus, the economic role of cocoa commodity has not been optimised when viewed from the aspect of the farmer. Crop diversification is a form of cultivation technology in which several prospective plants are developed as a source of farmers' income. The introduced interrupts are selected based on market opportunities and family food sources [16].

Optimization of farm income is carried out by cocoa farmers around the conservation forest area of TNLL through a diversification pattern between cocoa plants and local tubers. Revenue optimization is obtained when farmers can reduce production costs through efficient use of production inputs. The highest revenue optimization was obtained through the diversification pattern of sweet potato and cocoa plants with an increase in income of IDR. 28,382,068, as shown in figure 1.

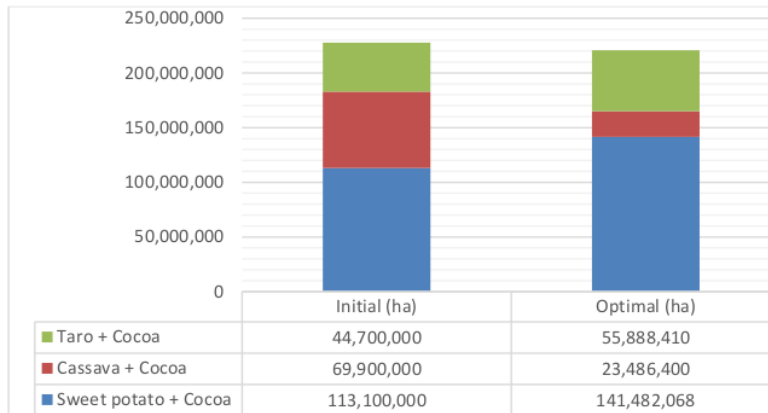


Figure 1. Optimization of revenue

3.3. Optimization of production input costs

The increase in production occurs due to the proper allocation of production inputs, resulting from a combination of production inputs of labor, pesticides, fertilizers and seeds. The ability to optimize the use of production inputs plays a very important role in an effort to maximize increased production yields while minimizing the use of production costs which directly affect farmers' income. Previous researches have shown that limited knowledge of farmers in using production inputs efficiently can hinder the optimization of farm income due to increased production input costs [17]. The use of appropriate and efficient production inputs can increase production and maintain the sustainability of farming and ensure the food security of farming families around the forest. Cultivation with a diversified pattern will function better in the sense that it does not require a lot of production inputs from outside, such as fertilizers and pesticides with higher diversity than monoculture systems. Optimizing the use of production input costs can be obtained by farmers through optimizing the use of production inputs through a diverse pattern of cocoa plants with local tubers. Optimizing the use of production input costs is obtained through the efficient allocation of fertilizer costs with a decrease of IDR. 3,346,300, as shown in Figure 2.

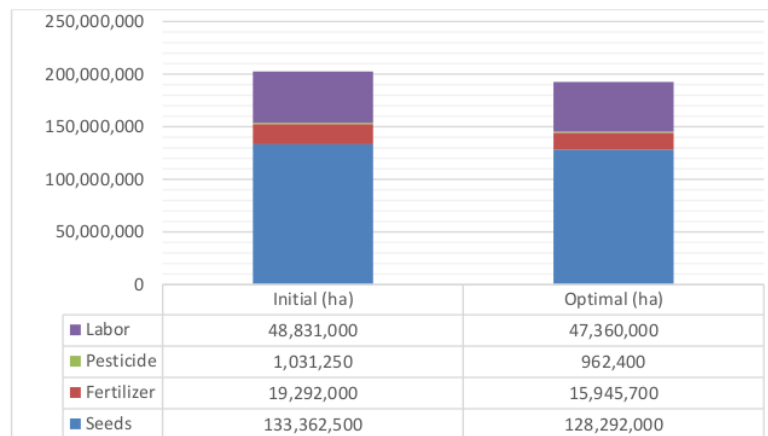


Figure 2. Optimization of production input costs

3.4. The nutritional content of tubers

Food security for farming families around the forest is not only oriented to rice, but is also supported by other types of local food commodities such as tubers, and food-producing trees such as sago and breadfruit. Diversification of cultivation and food consumption through the use of location-specific food commodity needs to be pursued. Food diversification aims to minimize dependence on one type of food which can cause food insecurity conditions [18]. Food security will be achieved if community's consumption comes from various sources, especially specific commodities as local food sources. Increasing the contribution of root crops as an alternative food source in meeting the need for quality food can have a significant influence on food security and the quality of marginal farmers' resources around the forest buffer zone of TNLL [19]. The quality of local tubers in the study area is determined by their nutritional content as shown in Figure 3.

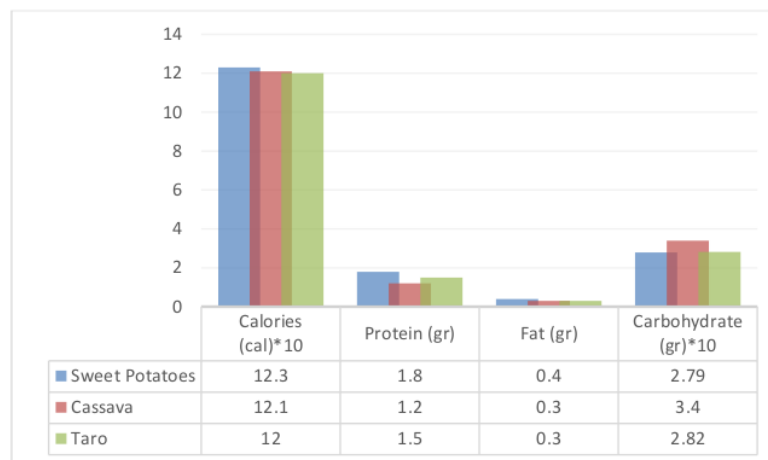


Figure 3. Nutrient value of tubers

In general, local tubers cultivated by farmers are plants that are intentionally planted by farmers, but do not have a commercial purpose. The harvested produce is consumed alone as a side dish or supplement and some are sold in the village market as additional income for the family. Farmers have not cultivated local tubers as their main business, although the marketing prospects are quite promising based on their taste and nutritional content [20]. Through the diversification pattern of local root crops with cacao, farmers around the forest can optimize their income while ensuring the availability and access to diverse and quality food in a sustainable manner. Based on Figure 3, it can be seen that sweet potatoes have higher calorie, protein and fat values than cassava and taro. However, cassava has a higher carbohydrate content than sweet potatoes and taro. Root crops have a lower nutritional value than rice and beans, especially protein and fat content, but have a fairly high carbohydrate content.

4. Conclusion

Land management carried out by cocoa farmers has not been optimal in increasing farmers' income and supporting food security in a sustainable manner. One of the main causes is the limited land area and capital owned by farmers and the lack of technological innovation related to plant cultivation that is beneficial from socio-economic and ecological aspects as well as ensuring food security and nutritional quality of farmer households around the forest. However, with limited land area and capital, farmers can improve their welfare by applying local wisdom-based cropping patterns by using existing biodiversity. Optimization of land through a diverse pattern of cocoa plants with local tubers can increase farmers'

income and not only ensure access to food needs of farmers' households, but also from the aspect of food quantity and quality with diverse nutritional content and value. Diversification is an effort and process to find the allocation of production factors, and available funds, between various forms of business and products as well as over time in order to improve the standard of living of farmer households. The diversification of cocoa plants with local tubers is expected to be a solution in technological innovation of agricultural cultivation, use of natural resources, productivity, employment opportunities, food security and nutritional adequacy of the community as well as improving the structure of the rural economy.

2. Acknowledgment

We acknowledge the support received from the Indonesia Ministry of Education and Culture Research and Technology (Kemendikbudristek), in particular Directorate of Resources, Directorate General of Higher Education, Research and Technology through the 2021 National Research Priority (PRN) Funding No. 046/E4/RA.00/2021.

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