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Spatial arrangement in alley cropping of moringa and crops to optimize farming income on small Potteran Island, Sumenep Regency

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Spatial arrangement in alley cropping of moringa and crops to optimize farming income on small Potteran Island, Sumenep Regency

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Abstract. Research on alley cropping was conducted as it contributes to soil and water conservation, in addition to improves landscapes aesthetics. This cropping system was introduced to farmers in the small island of Poteran, Sumenep Regency. Farmers on this island generally have narrow land and limited capital, hence intensification of farming with small capital but maximum production and income is needed. In an effort to obtain a high income, it is necessary to find the optimal spatial arrangement between hedgerow space and alley crops space. The spatial planning model reserached included three scenarios, i.e. two row, three row and four row moringa hedge crop by combining corn, peanut, and cassava as alley crops. To obtain optimal scenario, this research used alley cropping data from previous research conducted in Talango Village, Poteran Island, on an area of 0.16 ha. Subsequently, a linear program supported by a solver application in Microsoft Excel was used to determine the optimum spatial arrangement scenario. The results showed a two-row moringa scenario with cassava as alley crop produced the highest income with the lowest cost.

1. Introduction

The increasingly widespread of degraded agricultural land has led to the selection of planting systems that can provide ecological benefits in addition to economic benefits. One of the promising and developing cropping systems in a tropical land that provides ecological benefits is alley cropping system [1,2]. In this system, tree or bush plants are planted as hedges with wide spacing between rows so that they form aisles where food crops are produced. Alley cropping systems offer alternative marginal land utilization to improve the ecological function of the landscape, furthermore it enables sustainable food and biomass production [1]. Diversification of crop production is obtained in the alley cropping system, therefore it will reduce the farming risk. In addition, the application of alley cropping can improve land use efficiency and economic benefits [3].

Alley cropping system was being introduced to farmers on the small island of Poteran. The aim is to overcome the problem of agricultural land on this island which is poor in nutrients, especially N and low organic matter content [4]. In addition to increasing the income of farmers who generally have narrow arable areas and have limited capital, alley cropping is chosen because it had been proven to be able to increase farm income [5] while improving the function of agro-ecosystem services.

The alley cropping model developed is a combination of moringa and food crops. The selection of *Moringa oleifera* L. as a hedge plant because it can be used as soil and water conservation plants as



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proven in the research of the Faculty of Agricultural Technology, Cross River Obubra, Nigeria in the period 2009 - 2010 that with the growth of moringa plants, soil in the tropics or sub-tropics was improving [6]. The research also proved that moringa leaves which made into plant fertilizers were very good in fertility since they could increase the gradual harvest in a year on several types of plants. Moreover, Moringa plants also have high economic value because the nutritional content possessed has many benefits, one of which is the antioxidant content that can neutralize free radicals. Moringa leaf products increase as the demand for Moringa leaves also increases.

In optimizing the profits, there needs to be a spatial arrangement for moringa plants as hedgerows by providing enough space for food crops to grow. In this research, an attempt is made to increase the amount of land space for moringa plants, which was based on the moringa leaf economic value growth increment. Considering that the land is narrow and limited, the addition of land space for moringa goes hand in hand with the reduction in the area of planting food crops which is at risk. For this reason, it is necessary to consider using optimization analysis by providing several alternatives.

This research aims to obtain an optimal space-arrangement model in the alley cropping of moringa and crops in order to earn maximum income with a low-cost budget.

2. Methods

This study was conducted in Talango Village, Poteran Island, Sumenep regency, with consideration that alley cropping system had been introduced. In accordance with the research objectives, the spatial arrangement of alley cropping was designed into three scenarios, i.e. two rows, three rows, and four rows of Moringa plants as hedges.

The data needed in this study was obtained from the results of previous studies conducted by Ekawati et. al. [7] who applied the alley-cropping moringa model on a narrow area of 0.16 ha. The space arrangement on this model executes on two rows of moringa as hedgerows, and food crops (peanuts, corn, and cassava), through intercropping in alley row formed among hedgerows. The farming data analysis, which covers cost, receipt, and farming income along with crop production, were analyzed to generate planting cost unit per square (m^2). In order to gain an optimum income, the linear mathematical programming with a facility of solver assistance from Microsoft excel was applied. In this study, the food crop plant scheming was planted in the form of monoculture, thus the food crops consist of three objects, peanuts, corns, and cassavas.

The stages done for this study describes in the following procedures:

- Calculating planting area for moringa and crops, in which the total planting area is 87% of the land area, while 13% of the land area was used for ditches and rorak (dead-trench);
- Calculating the unit cost per m^2 for each commodity, taking into account the construction cost of ditches and rorak charged to all commodities;
- Determination of the linear programming mathematical equation that consists of objective function for minimizing costs (1), constraint function of land area (2), and limitation function (3), in order to obtain maximum income. Accordingly the symbolic pattern is as follows:

$$Z = \sum_{i=1}^n a_i x_i \quad (1)$$

$$\sum_{i=1}^n x_i \leq A \quad (2)$$

$$x_i \geq 0 \quad (3)$$

Annotation:

Z = crop farming total cost that need to be minimized (IDR)

a_i = commodity cost for i per m^2 (IDR / m^2)

x_i = optimal planting area from commodity type for i (m^2)

A = planting area (1441 m^2)

- d. Calculating the optimized spatial arrangement on alley cropping of moringa and crops through linear programming with the solver facility assistance of Microsoft excel, therefore minimal cost to gain maximal profits were obtained.
- e. Selection of optimum space arrangement scenario on alley cropping of moringa and crops.

3. Results and Discussions

3.1 Space Arrangement on the Existing Alley Cropping

The alley cropping system researched was a combination of moringa and crops (peanuts, local variety corn, cassava). These crops are commonly planted by the farmers in Poteran Island for years [8]. The alley cropping model was designed as a conservation farming model by constructing rorak (dead-trench) in the middle of land and ditch among partitions to increase the water absorption down the soil in the rainy season. The width of rorak and ditch was 13% of the planting area, while 87% of the land was for moringa plant and food crops. The moringa plant as hedgerows planted in two rows with the planting distance of 1 × 1.5 m. Moringa planting material came from seeds with the consideration that Moringa planted from seed is more resistant to termite attack. The food crops were planted through intercropping in alley row formed between hedgerows. The total land area used was 0.16 hectare.

The 1-year farming cost, revenue, and profit analysis per m² for each crops that became a model of alley cropping are presented in Table 1. This data was used as a foundation for determining which crops were selected as a component of alley cropping model.

Table 1. Unit cost, and revenue per m² of each commodity

Commodity	Total cost (IDR)	Revenue (IDR)
Peanuts	6,388.32	8,892.13
Corn	1,657.02	1,333.27
Cassava	1,371.74	3,830.02
Moringa	8,658.29	7,244.05

Notes: exchange rate 1 USD = IDR 14,225

3.2 The Minimum Cost Selection and Food Crop Planting Area

The data on 1-year farming cost, types of commodity, and the total number of population, utilized to determine food crops that have a minimum farming cost. The selected type of crops was used as an alley cropping component. Optimization through linear programming with solver application on crops commodity, aimed for cost minimization, resulted in cassava as the selected commodity. Cassava farming cost are presented in Table 2.

Table 2. The planting area and cost on each scenario

Commodity	Scenario	Planting Area (m ²)	Cost (IDR)
Cassava	1	937.92	1,289,397
	2	769.92	1,058,440
	3	601.92	827,484

3.3 Space Arrangement Scenario

There were three spatial arrangement scenarios studied, i.e. two rows, threerows, four rows of moringa as a hedgerow. The cassava commodity was combined with the moringa plant according to the scenario in order to implement a revenue analysis, as the results are presented in Figure 1. Of the three scenarios, the first scenario was the combination of two rows of moringa and cassava which had the highest revenue, with an area of moringa 504 m² and cassava 937.92 m². The alley cropping revenue from combination of moringa and cassava could still increase in the following years, since the analysis was

done when the moringa plants were only one year old. Moringa leaf production will increase in line with plant growth and increasing in age.

For a sustainable moringa-cassava alley cropping system production, it is essential to apply integrated nutrition management, by using organic matter, inorganic fertilizer, and biological source nutrition (N-fixing microorganisms, phosphate-solubilized microorganism) to maintain soil fertility and improving plant productivity [9]. As a complementary plant, cassava has a relatively high need of nutrients [10], even though the nutrient needs for root formation is lower than other plants [11]. The loss of nutrients through harvesting can be reduced by returning plant parts above ground, and preventing erosion [12].

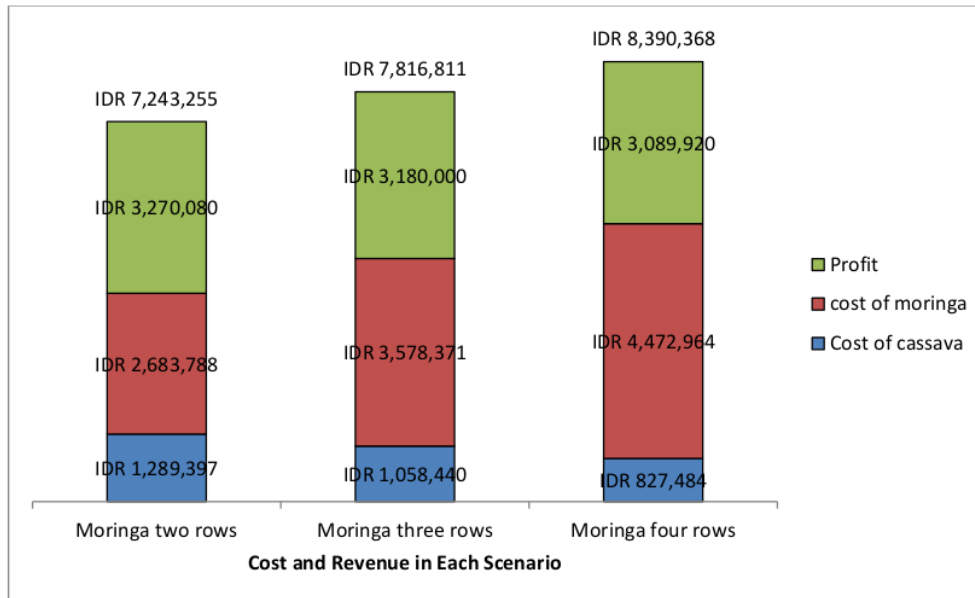


Figure 1. Optimization of moringa and cassava combination in each scenario

Aside from having financial benefits, the use of moringa as a hedge plant has ecological benefits, as old leaves, petioles, young stems from the leftover after harvest can be incorporated into the soil to add soil organic matter and increase soil nutrient levels, especially Nitrogen, considering the Nitrogen or protein content of the harvest residue are relatively high [13,14]. Therefore, the function of agroecosystem services will be improved.

4. Conclusions

According to the result of linear programming with solver assistance, it was obtained that the combination of moringa-cassava with spatial arrangement of two rows moringa as hedgerows produced the highest revenue compared to three or four rows of moringa spatial arrangement. This result can be a new insight related to the optimal spatial arrangement in alley cropping, considering that previous studies have not yet arrived at economic analysis and modeling using moringa as a hedgerow. This model has the potential to be adopted and developed, in order to increase annual income from farming, improve the community's economy, and provide ecological benefits. However, efforts are needed to maintain the sustainability of cassava production and preservation of soil fertility, therefore integrated nutrition management for further research is recommended.

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