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A Linear Programming Approach to Integrated Farming System of Black Sugar (Arenga pinnata) in West Bandung District, West Jawa, Indonesia.

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ABSTRACT

Most of small scale industries, in small villages of Indonesia, based on limited local resource relatively unsustain. In order to improve the sustainability of these industries it is necessary to develop strategy of optimization to obtain maximum profit and/or lowest expenditure. Villagers' livelihood in part of West Java relies mainly on the products originated from Aren (Arenga pinnata (Wurmb) Merr.), namely black sugar and Aren's fruits. In this study we applied linear programming (LP) technique for optimization of the industry in order to maximize gross margin from combination of workforce and capital. Data were collected from eighteen enterprises in the existing plan of 1 labor per day for black sugar production and 3 labors per day for fruit collecting and processing. The LP maximization model recommended concentration on black sugar production with production level at least 25.05 kg per day in order to obtain highest possible profit of IDR 259,307 per day. It is recommended that farmers develop diversification of products and entering new market for healthy food to improve gross margin.

Keywords: Linier programming, limited resources, profit, black sugar, aren's fruits

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INTRODUCTION

Loss of local biodiversity is the common feature of in forest area of Indonesia especially the area adjacted to village and human dwelling. Timber harvesting increase rate of forest destruction and ecosystem service loss provides by the forest. Under this circumstances, it is required to develop a more sustainable trade-offs between conservation and local livehoods [3]. One of the promising solution is by developing a agricultural system that directly link local livehoods and biodiversity conservation [26]. Under the system, the domestication of particular wild and native species may meet the economic needs of local people (such as income diversification) while in the same time contribute to biodiversity conservation [19, 14, 2].

In Indonesia, aren or black sugar palm (Arenga pinnata (Wurmb) Merr.) is a native tree species widely used by different ethnic groups in North Sulawesi, South East Sulawesi, North Sumatra, West Java, Central Java, East Java, East Kalimantan and West Kalimantan [20]. Aren is also identified as a priority species for human livelihood in Indonesia and Thailand [10] indicated by its nomenclature that comprises by 150 local names for Indonesia alone [12]. This tree has utilitize in various ways which depends on the local socioeconomic (religion, cultural) background, the availability of other natural resources (i.e. fuel-wood for sugar processing), and market opportunities [20]. Aren has major socioeconomic for the rural poor as diet and raw materials [6, 21]. On the other hand, it also contributes to the diets of wild animals, some are species of high conservation value such as Tonkean macaque (Macaca tonkeana) [23, 24], babi rusa (Babyrousa babyrussa) [4], bees (Apis cerana) [14], palm civets (Paradoxurus hermaphroditus Pallas) [11], and Sumatran orangutan (Pongo abelii) [27]. Moreover, in some ethnics, economic value of Aren play an important role for wild animal conservation as farmers believe that the best aren planters are the palm civets [18, 11].

West Java is recognized as major agricultural area and most populated area in Indonesia; hence there is huge possibility of conflict between agricultural practices and conservation efforts. In order to prevent huge biodiversity loss, it is necessary to implemented the strategy of domesticate economically important trees like aren. Total aren plantation in Indonesia about 70,000 ha and most of them located in West Java (14,204 ha) with total production of black sugar about 22,489 ton [1]. Total production of local black sugar still below market demand which is about 510.000 ton per year.

However, most Aren farmers only depend on the black sugar as income and neglected other non timber product of Aren such as the fruits [28]. Under this condition, most traditional small farmers live in poverty. Furthermore, despite the importance of aren for their livelihoods, very few farmers in West Java actively propagate or domesticate the species which also have been reported from other parts of Indonesia. Report showed that rate of development of new aren plantation in West Jawa was 0.92% and the black sugar productivity was drop at rate 3.26% per year (in 1980 to 1988) [17]. It is assume that farmers perception that aren trees are still abundant in the landscape may be a reason for farmers' reluctance to put in more effort for aren cultivation although only 26.5% of total trees could produces marketable amount of sugar (Gunawan, unpublished data). Old trees, low productivity, and unstable price could discourage farmers to continue their efforts and may create more pressure to biodiversity when farmers decides to changes their profession.

In order to improve the socioeconomic impact of aren to local community, it is necessary to develop the strategy which optimize the output of aren plantation. One of the most promising strategy is development of integrated farming system at aren plantation as this approach could improve the profit per space and time, provides economic insurance through product diversification, provides more jobs, and protect the environment [25]. There are some approaches to develop farming system, one of them is Linear Programming (LP) approach. Sistematic planning applies in this approach provides foundation for optimation plan through choice and combination of methods in order to improve profit and reduce cost based on available resources [5, 13]. Some studies in Indonesia applied this approach in order to develop strategies for optimization of some local products such as sugar [7], cattle [9], and rice [29].

Thus, this study was conducted to document the current practices in aren utilization in West Java area (especially in West Bandung District), to investigate the factors influenced profit of local aren plantation, and to defined optimum production and profit based on analysis of available resources in the area.

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MATERIALS AND METHODS

The study was conducted from May to July 2017 at Cinengah Village, Kecamatan Rongga, Kabupaten West Bandung, West Java. Main occupation of village member is farmer with total farming area around 2.490 ha, some of area allocated for Aren plantation.

There were three methods applied in this study, (1) Primary data collection by direct observation and survey method. The main subject of the survey was Aren farmers. In this study, 18 farmers were designated as correspondents of the survey and (2) Secondary data collection by references study and data collection from governmental institutions related to agriculture and economic development.

The Linear Programming Model

Various quantitative mathematical analysis tools have been developed to analyze and to provide supporting argument for decision making in agricultural research and farming system. Linear programming (LP) is an analysis technique that optimizes some linear objective functions subject to certain linear constraints in order to explore the optimum solution. In this study, LP selected to formulate the appropriate productivity level of Aren based on available workforce and capital to optimize the profit. Profit was determined by formula

$$\pi = \mathrm{TR} - \mathrm{TC}$$

Where π is maximum profit, TR is total revenue and TC is total cost

The models developed by LP technique can be maximizing or minimizing functions. In this study we developed a maximizing model as follows: Persamaan matematis fungsi tujuan dan kendala usahatani gula aren (X_1) dan kolang-kaling (X_2).

The objective function $Z_{max} = \sum_{i=1}^{j} C_i X_i$ (1)

Subjected to constraits $\sum_{i=1}^{n} \sum_{j=1}^{m} a_{ij} X_i \leq b_j$ (2)

Non-negative constraits $X_i \geq 0$ (3)

Where, Z_{max} = Maximizing objective function
X_i = Variables of decision
a_{ij} = Usage of resources coefficients
b_{ij} = Amounts of resources coefficients
c_i = Increase of units to optimize Z coefficients
i = 1, 2, 3, … n, variables number
j = 1, 2, 3, … m, constraints number

The objective function is to maximize the profit of local Aren based agroindustry based on availability of workforces and capital. In this study, we tested two constraints to profit:

a. Workforce consisted of number of men and women labors.
b. Capital consisted of production capital in cost and equipments.

Based on this, we developed linear programming function as

Workforces : $a_{11}X_1 + a_{12}X_2 \leq b_1$
Capital : $a_{21}X_1 + a_{22}X_2 \leq b_2$
$x1, x2, \ldots, xn \geq 0$

Where,

cj = Aren productivity (unit/month/m^2)
xi = Variable of decision (unit/month)

Z = Maximum profit (production (kg/month)
X_1 = Production of black sugar (Kg)
X_2 = Production of Aren fruits (Kg)

RESULTS AND DISCUSSION

Socioeconomi Characteristics of Farmers

A summary of the farmers in West Bandung District of West Java is presented in Table 1. The variables observed included age, education, household, laborer sex, experience, and number of laborers. In this study, availability of workforces and capital were applied as factors that affected the productivity of aren products with economic value (black sugar and fruits).

More workforces require for producing processed fruit than black sugar although the overall capital requires for production much lower. More workers in processed fruit production are due to longer and much complicated procedures required.

LP model of Workforces

Aren sugar produced twice a day while fruits collected once a day. Total workforce for aren sugar production was one person while two persons assigned for fruit collection and post harvest treatment. Both activities conducted by same team, which originated from same family. There were differences in payment between both work types. The average payment for aren production was IDR 8,814 (equal to US$ 0.65 with exchange rate US$13,500 = US$ 1). On the other hand, there were huge differences in average payment for fruit product activities as women received on average about IDR 500 (equal to US$ 0.04) per bin (1 kg) while men received IDR 10,000 per day (equal to US$ 0.74) due to differences in workload.

Table 1: Summary of descriptive of work forces characteristics of respondents in Cinengah Village

Variable	Sugar Production	Fruit products
Age	32-67 years old	35-50 years old
Education	Elementary level	Elementary level
Sex	Male	Male & Female
Experience	3 to 20 year	3 to 10 years
Number of laborers	1 labor/day (1 male)	3 labor / day (2 male, 1 female)

LP model of Capital

All capital invested to production of aren sugar and fruit product originated from household budget. Based on questioner and interview, daily investment was IDR 50,000 (equal to US$ 3.7) for labor wages while monthly capital investment of materials and equipments, on average, were IDR 59,876 for black sugar production and IDR 56,257 for processed fruits.

Other constraints that limit the development of local Aren industry in West Java District are the size of plantation and productivity level of arens. On average, the size of plantation per farmer is 4129 m^2. On the other hand, most of aren's trees owned by farmers were old, low in productivity (the numbers of productive trees were between 2 to 10 trees per farmers) and numbers (distance between trees is 3 to 5 m) due to lack of plantation management. All of farmers in this area are traditional farmers who did not apply plantation management. Under these conditions, the input for production of black sugar and processed aren's fruit were low and unpredictable, which limits the profit of the industry.

Optimum profit of integrated farming system of Aren (black sugar and fruits)

Local aren agro industry in West Java district produces two main products, black sugar and processed fruits. The production level of both products highly related to availability of workforces and capital. We developed LP models for utilization of both factors for production of black sugar and processed fruits (4) (5).

Workforces : $0{,}013\ X_1 + 0{,}015\ X_2 < 0{,}3$ (4)
Capital : $59.877\ X_1 + 56.258\ X_2 < 1.500.000$ (5)

Based on equation (4) and (5) with consideration of supply and demand condition, in order to obtain maximum profit total amount of black sugar and processed fruits required was 64.15 kg/month and 42 kg/month, respectively. However, return of investment (ROI) of black sugar much higher than processed fruits, 25% and 10%, respectively.

On the other hand, the market price of the processed fruits much lower compare to black sugar (IDR 9,660/kg compare to IDR 10,351/kg), which was became based of the linear equation for profit (6)

$$Z_{max} = 10.351\ X_1 + 9.660\ X_2 \quad (6)$$

X_1 and $X_2 > 0$

Prior to application of equation (6), we calculated the reduce cost of each aren's product. An optimum production system will have at least "zero" value for the reduce cost of the product [22]. Based on our calculation, we found reduce cost of processed fruit was -65,38 and 0 for black sugar. By applying equation (6) with consideration of ROI and reduce cost, we found that in order to produce maximum profit, all production line of aren should concentrate to produce black sugar. The lowest productivity level of black sugar to achieve maximum profit, which is IDR 259,307 per day, is 25.05 kg/day.

In our case, this model only work for farmers with large number of Aren trees that still producing sap, a raw material for black sugar production. As for farmers who possess unproductive Aren plantation, the replanting program should be conducted while they focused on the processed fruit production as main income. Diversification of fruits products, optimization of processing procedure, or entering new market may improve the income the farmers.

By applying the linear programming in answer report of workforces and capital, we find the "not binding" condition that indicated lack of interaction between supply and demand on both factors to production level. This condition could be relates to the lack of workforces for production activities. Based on our survey, in total only 5 workers available for both production of black sugar and processed fruit which became major limiting factor for production. On the other hand, number of productive trees showed "binding" condition that indicated strong interaction between supply and demand for production level of aren's products.

CONCLUSION

Best strategy to be apply in order to optimized the economic value of Aren, based on availability of capital and income at local Aren plantation in Cinengah village, is improving the productivity of aren sugar production to level of 25.05 kg per farmer with maximum profit estimated on IDR 259,307 day^{-1}.

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