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# Traditional plants in forest gardens of West Kutai, Indonesia: Production and financial sustainability

**MARTEN APUY, ABUBAKAR M. LAHJIE♥, B.D.A.S. SIMARANGKIR, YOSEP RUSLIM♥♥, ROCHADI KRISTININGRUM**

Faculty of Forestry, Universitas Mulawarman. Jl. Kuaro, Gunung Kelua, Samarinda Ulu, Samarinda 75119, East kalimantan, Indonesia. Tel./Fax.: +62-541-741033, 735379, ♥email: prof_abudir@yahoo.com, ♥♥ yruslim@gmail.com

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**Abstract.** *Apuy M, Lahjie AM, Simarangkir B.D.A.S, Ruslim Y, Kristiningrum R. 2017. Traditional plants in forest gardens of West Kutai, Indonesia: Production and financial sustainability. Biodiversitas 18: 1207-1217.* Our research on the first generation forest gardens (munaan) in West Kutai District, Indonesia, aimed (i) investigating the cultivation and the financial profit of various plants grown by the residents in the first generation forest gardens (munaan); (ii) finding out the financial feasibility level of the first generation forest gardens (munaan) cultivation by the residents. The subject of this research included farmers or people who cultivated the old/ first generation forest gardens as well as several plant commodities namely durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*), cempedak (*Artocarpus champeden*), langsat (*Lansium domesticum*), ihau (*Dimocarpus didyma*) (i.e. native Borneo longan), meranti (*Shorea* sp.) and kapur (*Dryobalanops aromatica*) trees. Five villages/kampongs were sampled, with each plot sized 20 m x 20 m. Biomass analysis stocks growth of meranti and kapur trees are using volume formula. While the fruit production was calculated by weighing the weight of the fruit. In order to find out the relationships among variables, a polynomial regression equation was employed to obtain the regression coefficient of determination ($R^2$). The bioeconomic analysis feasibility was done by using Pay Back Period (PP), Net Present Value (NPV), Net B/C ratio and IRR. The amount of revenue level for each variant of fruit (i.e. durian, rambutan, langsat, ihau, and cempedak was different depending on the volume of fruit production and the selling price. The total amount of revenue from the cultivation of kapur and meranti trees depended on the total volume of timber, which was based on their diameter and basal area multiplied by the price of the timber itself. These findings imply that the cultivation of first generation forest gardens (munaan) was feasible for the community. The calculated values of Pay Back Period, Net Present Value (NPV), Net B/C and IRR at the discount level factor of 5% were 19.3 years; IDR 30.004.000, 1.58 and 8.8% respectively.

**Keywords**: Bioeconomic, cultivation, forest gardens

## INTRODUCTION

In the reform era that began in 1997-1998, Indonesia has delegated authority over the management of natural resources, from central government to regional government. (Jayadi et al. 2014; Chaiphar et al. 2013). One instance is the forest area rehabilitation effort (Gonner and Seeland 2002). Family forest gardens have been considered one of the models of the secondary forest area utilization by empowering the local community members to cultivate the forest gardens with such plants as durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*), langsat (*Lansium domesticum*), cempedak (*Artocarpus champeden*), ihau (*Dimocarpus didyma*), Kapur (*Dryobalanops aromatica*) and meranti (*Shorea* sp.) trees (Winarni et al. 2017; Mulyoutami et al. 2009). The utilization of forest gardens has been an inherited practice by the sub-ethnic groups of Benuaq Dayak, Tunjung and Kutai. These forest gardens have been able to grow plants that are both suitable for the ecology of tropical forests in Kalimantan and have the agroforestry business potentials which can be developed in such secondary forest area (Crevello 2004; Chaiphar et al. 2013).

Furthermore, cultures have a very broad definition of land use, which include the community living with the use of natural resources and the environment (Fahrianoor et al. 2013). The concept of customary law is a participative way of thinking. Therefore, the tenure or ownership of forest and its natural resources both individually and/or communally are obtained by opening the forest areas for cultivation (Prasetyo et al. 2015). The cultivation done by individuals opening the land is permitted, given the ownership of the land property of that particular forest. This traditional system for obtaining a particular ownership of forest resource areas for cultivation has been regarded as the early stage that a community goes through in order to get to know the term ’tenure and property rights (Muliadi et al. 2017).

The Dayak community living around the forests initially earned their living by hunting, gathering, and fishing in the river and lakes (Rahu et al. 2014). This condition has changed, they have been familiar with the farming system, trading, raising cattles, planting, providing services, and being civil servants, as well as, employees in companies (Pamungkas et al. 2013). Communities with sustainable natural resource management are led to exploit their lands and produce high-tech machinery that destroys natural resources (Chusakul 2009). This indicates that there has been a diversification of occupations among the Dayak communities living around the forest areas (Guerreiro 2003). They work not only to fulfill the subsystem needs but also have given in to the commercialization of trading forest commodities (Ivo 2012). The particular activities of gathering forest products, farming, raising cattles and working in the fields have, recently, been done not only to feed the family, but some are also sold in the markets, in which the economic activities done cannot be separated from the farming practices in the dry fields or the swidden agriculture, with paddy rice as the main crop (Hongo 2009).

Forest gardens are considered a dynamic form of a social, economic, and ecological process of the traditional communities, in which the realization of forest gardens for the farmers living in the villages around the forest areas will be a pattern created by the ideas of sustainable natural resources management (Kettle 2010). Furthermore, (Wiersum 2004; Wilcove and Koh 2010) predicts that the process of forming forest gardens happens gradually. At the beginning, the fruit seeds which were accidentally brought from the forests to be consumed, grew into plants and eventually gave some advantages. From these experiences, further predictions were made, such as a decision to cultivate or let the plant grow naturally when opening the area for cultivation and residence.

The cultivation of fruit plants by the villagers have been a familiar activity practiced for centuries. The cultivation has been done both purposively and accidentally with the random cultivation distance in the areas around the villagers' huts (their temporary logging) or their homes, during the cultivating time. The land use has been done by a swidden agriculture system, using slash-and-burn techniques, started by cultivating rice crops and fruit trees done gradually from year to year (Meijaard 2013).

In managing community-based forest gardens, farmers always have limited resources (i.e. the size of the cultivation areas, labors, production facilities, capital). Cost analysis plays an important role in taking a managerial decision; therefore financial feasibility is defined as a form of financial analysis. In order to find out the amount of investment done for a particular extent of cultivation areas, financial analysis is deemed as necessary (Lahjie 2016).

## MATERIALS AND METHODS

This study was undertaken in forest gardens at Barong Tongkok Subdistrict, West Kutai District, East Kalimantan Province, Indonesia. The size of rehabilitation area was around 3,000 ha. The study sites were located at 1°32'-1° 04' 22 North Latitude (Figure 1).

The sites visited as research location in Barong Tongkok sub district of West Kutai, East Kalimantan Province are Geleo Asa villages, Gemuhan Asa, Muara Asa, Ongko Asa and Ombau Asa. The visit started from 1991 to 2015 with interval of one-year interval, from June to December over a month, to determine the simulation of fruit production and growth of stocks for twenty-five years. Production over twenty-five years is a simulation. The forest garden began to be researched from the age of 30 years.

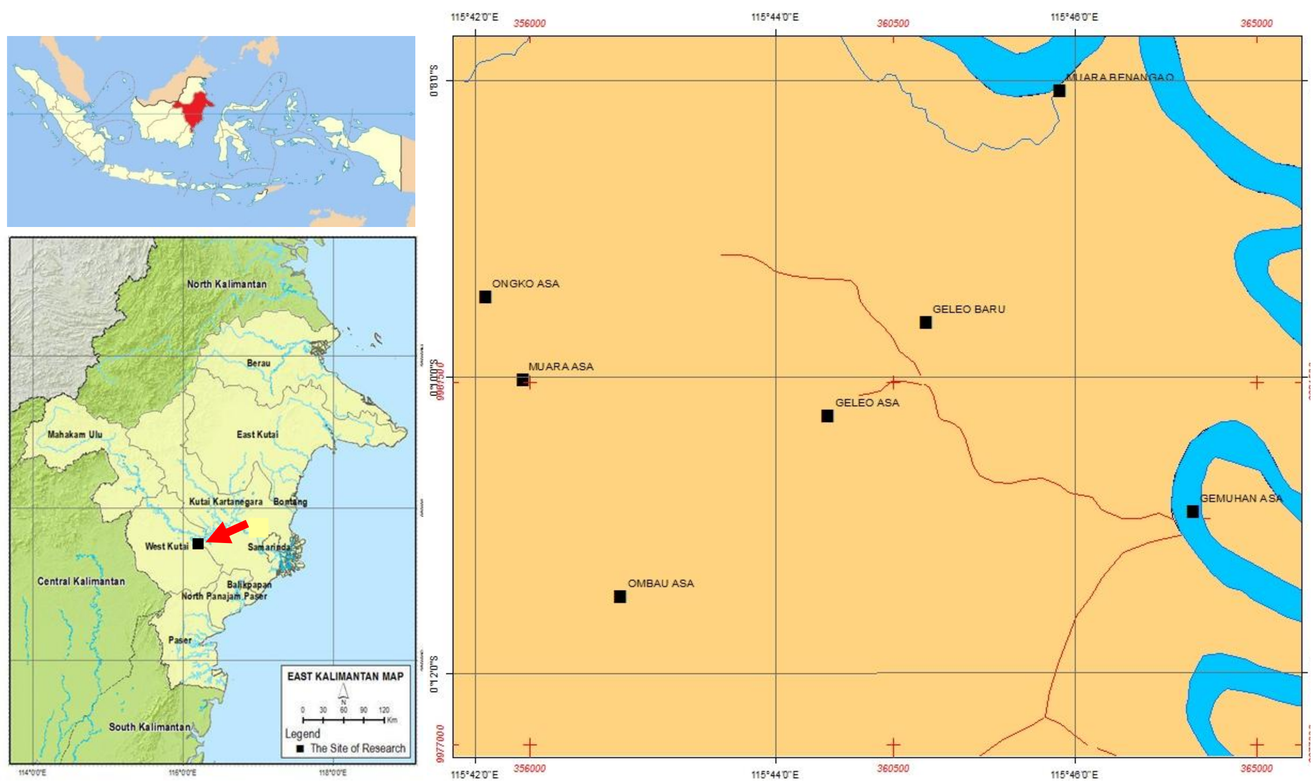


**Figure 1.** Location studies at Geleo Asa villages, Gemuhan Asa, Muara Asa, Ongko Asa and Ombau Asa of Barong Tongkok sub-district (■) West Kutai district of East Kalimantan, Indonesia

The variables that had been measured as scientific data and had been analyzed based on the scientific principles were then analyzed as follows: The diameter of the tree measured using a measuring tape and the height of the tree was measured by using clinometers. Analyzed the simulation of increment, basal area, and the potential of stands. The number of fruit tree samples and wood biomass of 50 % with varying diameters. The timber production was calculated by simulation analyzing the growth increment of the woody trees in a particular measurement time span (cycle), which included Period Annual Increment (PAI) and Mean Annual Increment (MAI).

$$TV = \frac{1}{4}\pi\, d^2 h\, t\, f\, n$$

Where: TV = Total standing volume, d = diameter at breast height, h = branch-free height, f = form factor, n = number of trees $ha^{-1}$

$$MAI = \frac{V_t}{t}$$

Where: MAI = mean annual increment, $V_t$ = total standing volume at age t, t = tree age

$$PAI = \frac{V_t - V_{t-1}}{T}$$

Where: PAI = period annual increment, $V_t$ = total standing volume at age t, $V_{t-1}$ = total standing volume at age t-1, T = time interval between each measurment age.

Analysis of maximum production of forest garden fruit trees for a particular measurement period (cycle) was done by calculating average revenue (AR) and margin revenue (MR).

$$AR = \frac{R_t}{t}$$

Where: AR = average revenue, $R_t$ = total revenue at age t, t = tree age

$$MR = \frac{R_t - R_{t-1}}{T}$$

Where: MR = margin revenue, $R_t$ = total standing revenue at age t, $R_{t-1}$ = total standing revenue at age t-1, T = time interval between each measurment age.

As the benefit and costs associated with woody trees and fruits-based systems occur over many years. So, the criterion used in evaluating the business feasibility was the net present value (NPV), Benefit and Cost ratio (B/C ratio) and internal rate of return (IRR) (Graves et al. 2007; Guerra et al. 2014; Dhavale and Sarkis 2017).

$$NPV = \sum_{t=0}^{t=T} \frac{(R_t - V_t - A_t)}{(1 + i)^t}$$

Where NPV was the net present value of the arable (IDR $ha^{-1}$), $R_t$ the revenue from the enterprise (including subsidies) in year t (IDR $ha^{-1}$),$V_t$ the variable cost in year t (IDR $ha^{-1}$), $A_t$ the asignable fixed cost in year t (IDR $ha^{-1}$), t the time horizon (years), and i was the discount rate.

$$B/C = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}}$$

Where: B = Benefit, C= Cost, r= rate, t= the time horizon (years).

IRR is a mean annueal return derived from an investment and expressed in percentage (Graves et al. 2017). IRR value indicates an interest rate that can be paid by a business, or in other words, the ability to gain income from the cost invested.

$$IRR = i_1 + \frac{(i_2 - i_1)\,(NPV_1)}{(NPV_1 - NPV_2)}$$

Where: $NPV_1$ = positive NPV, $NPV_2$ = negative NPV, $i_1$ = interest rate when NPV is positive, $i_2$ = interest rate when NPV is negative.

The weighing of fruits by using scales to find out the amount of fruit production and then calculate the total revenue. We studied the data of the relationships among variables by using the determination coefficient ($R^2$), including the correlation between age with total or production and age and total revenue. The analysis of financial feasibility of the forest gardens by using several investment criteria, according to Lahjie (2004) as follows: (i) Payback Period (PP); (ii) Net Present Value (NPV); (iii) Net Benefit Cost Ratio (Net B/C); (iv) Internal rate of return (IRR).

## RESULTS AND DISCUSSION

### Forest gardens diversity

The Tonyooi Dayak people in West Kutai, Indonesia used traditional farming in cultivating their land, namely shifting/ rotating cultivation system. This kind of farming system would not affect the globalization factor because it would not be influenced by mechanization, capitalization or finance as well as the use of chemical fertilizers, hence a good practice to be maintained in West Kutai.

Furthermore, Barong Tongkok Village is a highland with the height ranging from 80 m to 380 m above sea level. The culture of shifting/rotating the cultivation system was considered as suitable, especially related to the available agricultural equipment and technology in the past as well as other factors that could support the marketing of the agricultural products. The shifting/rotating cultivation calendar focused on rice as the main crop, with others such as corns, vegetable and spices as supplementary crops (Hongo 2009). Thus, suitable shifting/ rotating cultivation strategy had to be employed. Parts of of the field would be cultivated with rice, corn, spices such as turmeric, ginger and *Curcuma xanthorrhiza* (Javanese turmeric), vegetables such as tomatoes, chillies, string beans and eggplants, fruits such as rambutan (*Nephellium lappaceum*), durian, cempedak, mangoes, guavas, langsat and others, other plants such as candlenuts, dammar, rattan, natural rubber and forest timber for building houses. This cultivation area has been called munaan. Munaan was normally maintained for hundreds of years, which could be seen from the existence of trees with diameters larger than an extent of an adult's hug, therefore most munaan had been considered as the community forest gardens.

Moreover, in that particular plot, there were varieties of rice cultivated at the beginning of the phase. Those varieties of rice were cultivated together with such spices as ginger, turmeric and Javanese turmeric. Rice and the spices were cultivated in a year time. Afterwards, the field was let uncultivated for a while because it would be used later on for cultivating such vegetables as chillies, tomatoes, string beans and corns for a year or two. For the year after, the field would be cultivated with varieties of fruits such as rambutan, durian, langsat, ihau, and cempedak, as well as a variety of yearly plants such as meranti and kapur trees.

Rice produced per one hectare of field was three tonnes, gaining the revenue of IDR 12,000,000. Spices which were grown in between the rice crops gained the revenue of IDR 2,000,000 $ha^{-1}$, with the assumed price per kilogram of IDR 15,000. Thus, the total amount of spice production was 133.33 kgs.

After cultivating rice and spices, the fields owned by the Tonyooi Dayak people were rested for a while and then cultivated again with vegetables namely corns, chillies and string beans. The revenue from corns was IDR 8,700,000, with the assumed individual price of the corn of IDR 3000/cob. This indicated that the total amount of corn production was 2900. Meanwhile, the revenue obtained from chillies and string beans amounted to IDR 5,000,000 and IDR 2,000,000 respectively.

The cultivation of the long-lived fruit trees and plants in the forest gardens was done after the cultivation of the vegetables. The fruits in the long-lived category included durian, langsat, cempedak, ihau and rambutan . Meanwhile, the yearly plants included meranti and kapur trees. These fruits experienced two forest gardens cycles, namely the first generation and the second generation. These fruits initially could only reach particular ages, to be followed by other cycles (next generations).

**The simulation of forest gardens production**

The first generation forest gardens would usually be preserved and maintained for years, as indicated by the existence of trees with diameters bigger than the extent of an adult's hug. Therefore, there had been a lot of forest gardens (munaan) opened inside the forests. Furthermore, concerning the varieties and the ages of the plants, the first generation forest gardens comprised of durian, langsat, ihau and cempedak, which could live up to 90 years.

*Durian (*Durio zibethinus*) trees*

Durian trees which were cultivated in the first generation forest gardens reached the age of 90 years old. These durian trees started producing fruits at the age of 15 years old until 90 years old. The production and the revenue from durian trees can be seen in Table 1.

It could be explained that the number of durians trees cultivated in the first generation forest gardens which started producing fruits at the age of 15 years old was 16, with the total amount of production of 245 kgs (Table 1). This means that 1 durian tree produced a total of 15 kgs fruits. In addition, the price of the durian fruit per kilogram was IDR 10,000; therefore at the age of 15, the total revenue was IDR 2,450,000. Optimum revenue was reached at the age of 50 years old, with the same number of trees. Thus, the total production $ha^{-1}$ was 966 kgs. The average production was 60 kgs and the total revenue was IDR 9,700,000. Then at the age of 90 years old, the total production of these 16 trees was 1.365 kgs. The average of fruit production per tree was 85 kgs. The price of the durian fruit was IDR 10.000 $kg^{-1}$; therefore the total revenue was IDR 13,700,000. The graphic of annual average revenue (AR), as well as marginal revenue of the cultivated durian in the first generation forest gardens based on the obtained data in Table 1, could be estimated systematically as illustrated in Figure 1.

The intersection of the optimal durian revenue in the first generation forest gardens occurred at the age of 50 years old with the total revenue of IDR 9,700,000, AR value of 193,200 IDR $ha^{-1}$ $year^{-1}$ and MR value of 192,000 IDR $ha^{-1}$ $year^{-1}$ (Figure 2). The relationship among the total production, total revenue and age can be seen in Figure 3.

From the regression analysis, the relationship between age and the total production of durian cultivated in the first generation forest gardens as well as the relationship between the age and total revenue indicated a linear relationship with a series graphic and had the regression value of 99.88 % (Figure 3).

*Langsat (*Lansium domesticum*) trees*

The age of the langsat trees that were cultivated in the first generation forest gardens were 90 years old. The langsat trees start producing their fruits at the age of 10 years. The production and revenue of the langsat trees can be seen in Table 2.

The langsat trees cultivated in the first generation forest gardens started producing at the age of 10, with the number of fruit trees as many as 160 and the total production of 240 kgs (Table 2). On average, one langsat tree produced 2 kgs of fruits and the price of langsat fruits was IDR 4000 $kg^{-1}$; thus at the age of 10 years old the total revenue obtained would amount to IDR 1,000,000. The optimal revenue for langsat trees would be obtained at the age of 50 years old with the number of fruit trees as many as 128. The total production $ha^{-1}$ of the langsat trees was 1512 kg $ha^{-1}$ and the average production of the langsat trees was 12 kgs with a total revenue of IDR 6,000,000. At 90 years old, the number of cultivated langsat trees amounted to 100 trees. The total production of langsat fruit was 2498 and the average production of langsat fruit per individual tree was 25 kgs.

**Table 1**. The Simulation of production and total revenue from durian (*Durio zibethinus*) trees in the first generation forest gardens

| Age | n | TR | AR | MR | TP |
|---|---|---|---|---|---|
| 15 | 16 | 24 | 1.632 | - | 245 |
| 20 | 16 | 35 | 1.728 | 2.016 | 346 |
| 25 | 16 | 45 | 1.800 | 2.088 | 450 |
| 30 | 16 | 56 | 1.856 | 2.136 | 557 |
| 35 | 16 | 66 | 1.893 | 2.112 | 662 |
| 40 | 16 | 77 | 1.920 | 2.112 | 768 |
| 45 | 16 | 87 | 1.933 | 2.040 | 870 |
| 50 | 16 | 97 | 1.932 | 1.920 | 966 |
| 55 | 16 | 104 | 1.898 | 1.560 | 1044 |
| 60 | 16 | 111 | 1.850 | 1.320 | 1110 |
| 65 | 16 | 116 | 1.791 | 1.080 | 1164 |
| 70 | 16 | 121 | 1.731 | 0.960 | 1212 |
| 75 | 16 | 125 | 1.672 | 0.840 | 1254 |
| 80 | 16 | 129 | 1.616 | 0.780 | 1293 |
| 85 | 16 | 133 | 1.564 | 0.720 | 1329 |
| 90 | 16 | 137 | 1.517 | 0.720 | 1365 |

Notes: n: number of trees ha$^{-1}$; TR: total revenue (x.IDR100.000); AR: Average Revenue (IDR ha$^{-1}$ yr$^{-1}$); MR: Marginal Revenue (IDR ha$^{-1}$ yr$^{-1}$); TP: Total Production

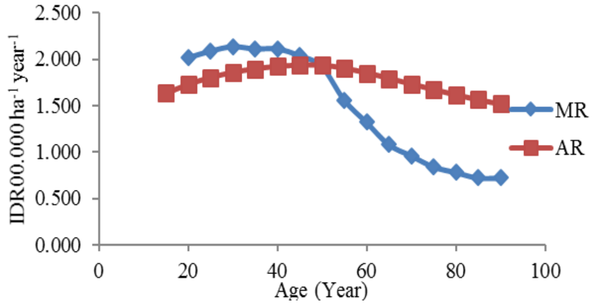


**Figure 2**. Average revenue (AR) and marginal revenue (MR) of durian (*Durio zibethinus*) in the first generation forest gardens for data from Table 1.

**Table 2**. The simulation of production and total revenue of langsat (*Lansium domesticum*) fruits from the first generation forest gardens

| Age | n | TR | AR | MR | TP ha$^{-1}$ |
|---|---|---|---|---|---|
| 10 | 160 | 10 | 0.96 | - | 240 |
| 15 | 144 | 15 | 1.01 | 1.10 | 378 |
| 20 | 144 | 21 | 1.04 | 1.12 | 518 |
| 25 | 144 | 27 | 1.07 | 1.21 | 670 |
| 30 | 144 | 33 | 1.09 | 1.21 | 821 |
| 35 | 144 | 40 | 1.14 | 1.38 | 994 |
| 40 | 144 | 48 | 1.19 | 1.56 | 1188 |
| 45 | 144 | 54 | 1.21 | 1.38 | 1361 |
| 50 | 128 | 60 | 1.21 | 1.21 | 1512 |
| 55 | 128 | 66 | 1.20 | 1.10 | 1650 |
| 60 | 128 | 71 | 1.19 | 1.08 | 1785 |
| 65 | 128 | 77 | 1.18 | 1.02 | 1913 |
| 70 | 128 | 82 | 1.17 | 1.02 | 2040 |
| 75 | 115 | 86 | 1.15 | 0.96 | 2160 |
| 80 | 110 | 91 | 1.14 | 0.96 | 2280 |
| 85 | 100 | 96 | 1.13 | 0.90 | 2393 |
| 90 | 100 | 100 | 1.11 | 0.84 | 2498 |

Notes: n: number of trees ha$^{-1}$ ; TR: total revenue (x.IDR 100.000); AR: Average Revenue (IDR ha$^{-1}$ yr$^{-1}$); MR: Marginal Revenue (IDR ha$^{-1}$ yr$^{-1}$); TP: Total Production

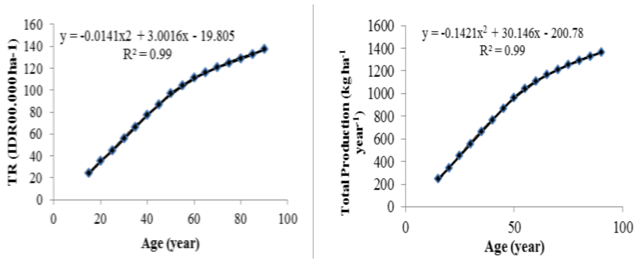


**Figure 3**. The Relationship between the age and total production (*left*) and the Relationship between age and total revenue (*right*) of the durian (*Durio zibethinus*) cultivated in the first generation forest gardens

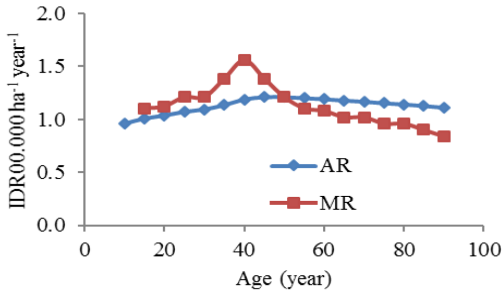


**Figure 4**. Average revenue (AR) and marginal revenue (MR) of langsat (*Lansium domesticum*) in the first generation forest gardens

The price of langsat fruit was IDR 4000/kg, so the total revenue was IDR 10,000,000. The graph for annual average revenue (AR) and marginal revenue (MR) of langsat trees is displayed in Figure 4.

The intersection of optimal revenue for langsat trees cultivated in the first generation forest gardens was found at the age of 50 years, with the total revenue of IDR 6,000,000 (Figure 4). Both AR and MR values were 121,000 IDR ha$^{-1}$ year$^{-1}$. The graphic of the relationship among the total production, total revenue, and age can be seen in Figure 5. The regression analysis result indicated a linear relationship among the age, total production and total revenue of the langsat trees cultivated in the first generation forest gardens (Figure 5). The regression value was 99.87%.

*Ihau (*Dimocarpus didyma*) trees*

The ihau trees which were cultivated in the first generation forest gardens reached the age of 90 years old. These ihau trees start producing fruits from the age of 30 years old. The production and revenue can be seen in Table 3.

Fruits from ihau trees cultivated in the first generation forest gardens started producing at the age of 30 years old, with as many as 24 trees fruiting. The total production was 114 kgs ha$^{-1}$. The price of ihau fruit kilogram $^{-1}$ was IDR 9000; therefore at the age of 30 years old, the total revenue was IDR 1,026,000. The ihau trees obtained the optimal

**Table 3.** The Simulation of production and total revenue of ihau (*Dimocarpus didyma*) fruits from the first generation forest gardens

| Age | n | TR | AR | MR | TP ha$^{-1}$ |
|---|---|---|---|---|---|
| 30 | 24 | 10 | 0.342 | - | 114 |
| 35 | 24 | 12 | 0.343 | 0.348 | 133 |
| 40 | 24 | 14 | 0.345 | 0.360 | 153 |
| 45 | 24 | 16 | 0.347 | 0.360 | 173 |
| 50 | 24 | 17 | 0.348 | 0.360 | 193 |
| 55 | 24 | 19 | 0.348 | 0.348 | 213 |
| 60 | 24 | 21 | 0.347 | 0.336 | 231 |
| 65 | 24 | 23 | 0.346 | 0.336 | 250 |
| 70 | 16 | 24 | 0.345 | 0.324 | 268 |
| 75 | 16 | 26 | 0.343 | 0.324 | 286 |
| 80 | 16 | 27 | 0.341 | 0.312 | 303 |
| 85 | 16 | 29 | 0.340 | 0.312 | 321 |
| 90 | 16 | 30 | 0.337 | 0.300 | 337 |

Notes: n: number of trees ha$^{-1}$; TR: total revenue (x.IDR100.000); AR: Average Revenue (IDR ha$^{-1}$ yr$^{-1}$); MR: Marginal Revenue (IDR ha$^{-1}$ yr$^{-1}$); TP: Total Production

revenue at the age of 65 years old, with the number of fruit tree as many as 24 trees. Therefore, the total production ha$^{-1}$ for ihau fruits was 250 kgs ha$^{-1}$ and the total revenue was IDR 2,250,000. At the age of 90, there were 16 fruit trees. The total production of ihau fruits amounted to 337 kgs ha$^{-1}$. The price of ihau fruit was IDR 9000 pieces$^{-1}$, thus the total revenue was IDR 3,033,000.

The intersection of optimal revenue for ihau fruits in the first generation forest gardens occurred at the age of 65 years old (Figure 6). The total revenue was IDR 2,250,000 with the AR and MR values amounting to 34,600 IDR ha$^{-1}$ year$^{-1}$ and 33,600 IDR ha$^{-1}$ year$^{-1}$ respectively. The relationship between total production, total revenue and age in the forms of graphs can be seen in Figure 7. The graph for the annual Average Revenue (AR) and Marginal Revenue (MR) of the ihau fruits is displayed by Figure 6. The relationships between age and total production as well as age and total revenue were linear with a polynomial graph, obtaining a regression value of 100% (Figure 7).

*Cempedak (*Artocarpus champeden*) trees*

Cempedak trees cultivated in the first generation forest gardens reached the age of 90 years old. These cempedak trees started producing fruits from the age of 10 years. The production and revenue will be displayed in Table 4.

Cempedak trees cultivated in the first generation started producing from the age of 10 years old, with the number of fruit trees as many as 112 (Table 4). The total production was 338 kgs. Moreover, the price of cempedak fruit kilogram ha$^{-1}$ was IDR 3000, so at the age of 10 years old, the total revenue was IDR 1,014,000. The optimal revenue for cempedak was obtained at the age of 50 years, with 112 fruit trees. The total production hectare$^{-1}$ was 1792 kgs and the total revenue was IDR 5,376,000. Furthermore, at the age of 90 years old, with 32 fruit trees, the total production of cempedak was 2200 kgs. The price of the fruit was IDR 3000 kgs$^{-1}$; therefore the total revenue was IDR 6,600,000. The graph of the annual Average Revenue (AR) and Marginal Revenue (MR) for cempedak trees cultivated in the first generation forest gardens is illustrated by Figure 8.

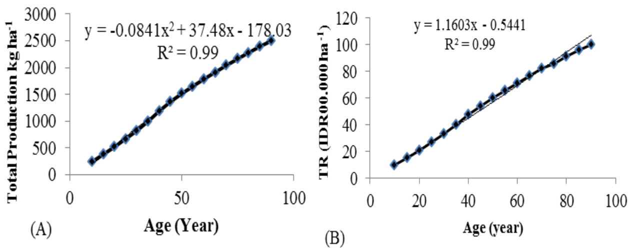


**Figure 5**. The Relationship between age and total production (*left*) and the relationship between age and total revenue (*right*) of langsat (*Lansium domesticum*) cultivated in the first generation forest gardens

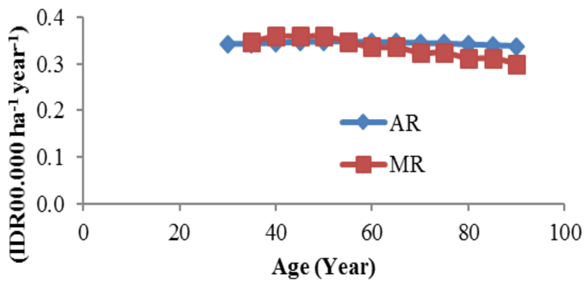


**Figure 6.** Average revenue (AR) and marginal revenue (MR) of ihau (*Dimocarpus didyma*) in the first feneration forest gardens for data from Table 3.

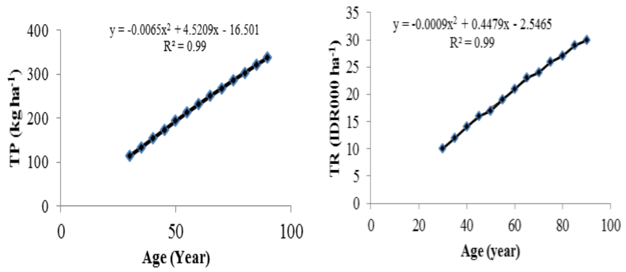


**Figure 7.** The relationship between age and total production (*left*) and the relationship between age and total revenue (*right*) of ihau (*Dimocarpus didyma*) trees cultivated in the first generation forest gardens

The intersection for the optimal revenue of cempedak cultivated in the first generation forest gardens was found at the age of 50 years old, with the total revenue of IDR 5,376,000, AR and MR values of 107,520 IDR ha$^{-1}$ year$^{-1}$ and 107,520 IDR ha$^{-1}$ year$^{-1}$ respectively. The illustrations of relationship between the total production, total revenue and age can be seen in Figure 9.

The regression analysis indicated a linear relationship between age and total production as well as between age and totatl revenue, with a polynomial graph, obtaining a regression value of 99.49% (Figure 9).

**Table 4.** The simulation of production and total revenue of cempedak (*Artocarpus champeden*) fruits from the first generation forest gardens

| Age | n | TR | AR | MR | TP ha$^{-1}$ |
|---|---|---|---|---|---|
| 10 | 112 | 10 | 1.01 | - | 338 |
| 15 | 112 | 15 | 1.02 | 1.02 | 508 |
| 20 | 112 | 20 | 1.02 | 1.03 | 681 |
| 25 | 112 | 26 | 1.03 | 1.05 | 856 |
| 30 | 112 | 31 | 1.03 | 1.06 | 1033 |
| 35 | 112 | 37 | 1.05 | 1.12 | 1220 |
| 40 | 112 | 42 | 1.06 | 1.12 | 1407 |
| 45 | 112 | 48 | 1.08 | 1.24 | 1.613 |
| 50 | 112 | 54 | 1.08 | 1.08 | 1.792 |
| 55 | 80 | 56 | 1.03 | 0.53 | 1.880 |
| 60 | 75 | 59 | 0.98 | 0.48 | 1.960 |
| 65 | 70 | 61 | 0.93 | 0.36 | 2.020 |
| 70 | 55 | 62 | 0.89 | 0.36 | 2.080 |
| 75 | 50 | 64 | 0.85 | 0.24 | 2.120 |
| 80 | 45 | 65 | 0.81 | 0.24 | 2.160 |
| 85 | 32 | 65 | 0.77 | 0.12 | 2.180 |
| 90 | 32 | 66 | 0.73 | 0.12 | 2.200 |

Notes: n: number of trees ha$^{-1}$; TR: total revenue (x.IDR100.000); AR: Average Revenue (IDR ha$^{-1}$ yr$^{-1}$); MR: Marginal Revenue (IDR ha$^{-1}$ yr$^{-1}$); TP: Total Production

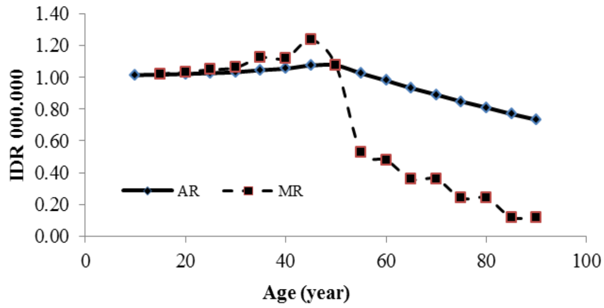


**Figure 8** . Average revenue (AR) and marginal revenue (MR) of Cempedak (*Artocarpus champeden*) in the First Generation Forest gardens for data from Table 4.

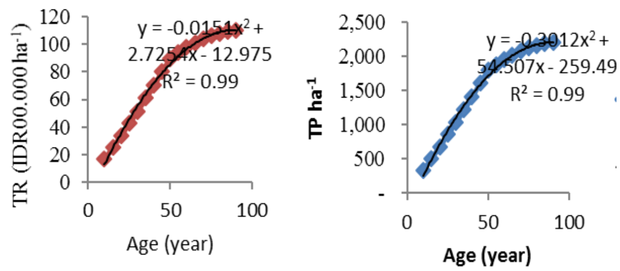


**Figure 9.** The relationship between age and total production (*left*) and the relationship between age and total revenue (*right*) of cempedak (*Artocarpus champeden*) cultivated in the first generation forest gardens

*Rambutan (*Nephelium lappaceum*) trees*

Rambutan trees cultivated in the first generation forest gardens reached the age of 35 years old. These trees started producing fruit from the age of 5 years old to 35 years old. The production and the revenue are illustrated in Table 5.

Rambutan trees cultivated in the first generation forest gardens started producing at the age of 5 years old, with 60 fruit trees and the total production of 3500 kgs. The price of the fruit kilogram$^{-1}$ was IDR 3000; therefore at the age, the total revenue was IDR 10,500,000. The optimal revenue for rambutan happened at the age of 15 years old, with 40 fruit trees. The total production hectare$^{-1}$ was 12,000 kgs and the total revenue was IDR 36,000,000. In addition, at the age of 35, with 20 fruit trees, the total production was 14,000 kgs whereas the total revenue was IDR 42,000,000. The graphic illustration for the annual Average Revenue (AR) and Marginal Revenue (MR) of rambutan trees can be seen in Figure 10.

The intersection of the optimal revenue for rambutan cultivated in the first generation forest gardens can be found at the age of 15 years old, with the total revenue of IDR 36,000,000, AR and MR values of 2,400,000 IDR ha$^{-1}$ year$^{-1}$ and 2,600,000 IDR ha$^{-1}$ year$^{-1}$ respectively. The graphic illustration of the relationship between the total production, total revenue and age can be seen in Figure 11.

The regression analysis showed a linear relationship between age and total production as well as age and total revenue, with a polynomial graph and the regression value of 99.53% (Figure 11).

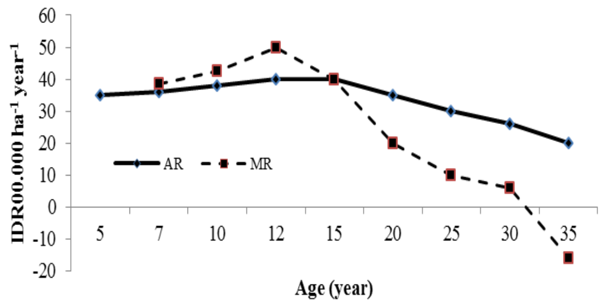


**Figure 10**. Average revenue (AR) and marginal revenue (MR) of rambutan (*Nephelium lappaceum*) in the first generation forest gardens

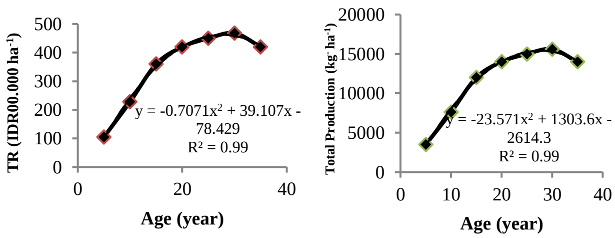


**Figure 11**. The relationship between age and total production (*left*) and the relationship between age and total revenue (*right*) of rambutan (*Nephelium lappaceum*) trees cultivated in the first generation forest gardens

*Meranti (*Shorea *sp.) trees*

Meranti trees in the first generation forest gardens reached the age of 90 years old, yet the number of the cultivated trees was only 8. Meranti trees at the age of 5 years old had a diameter of 12 centimeters with the average height of 11 meters. The optimal increment of meranti trees was reached at the age of 40 years old with the average diameter of 44 centimeters and the average height of 21 centimeters. The data for meranti increment production can be seen in Table 6. Meranti trees reached their optimal increment at the age of 40 years old, with the mean annual increment of 0.43 $m^3$ $ha^{-1}$ $year^{-1}$, current annual increment of 0.44 $m^3$ $ha^{-1}$ $year^{-1}$, and total volume of 17.11 $m^3$ (Table 6). The systematic estimation of MAI and CAI graph is displayed in Figure 12. The graphic illustration of the relationship between total volume and age can be seen in Figure 13.

*Kapur* (Dryobalanops aromatica) *trees*

Kapur trees in the first generation forest gardens reached the age of 90 years old and the number of trees cultivated was 8 (eight). Kapur trees at the age of 5 years old had a diameter of 10 centimeters, with the average height of 9 meters. The optimal increment of kapur trees was reached at the age of 40 years old, with the average diameter of 41 centimeters and average height of 20 meters. The data for the kapur trees increment production can be seen in Table 7. The regression analysis result indicated a linear relationship between age and total volume, with a polynomial graph and a regression value of 99.88% (Figure 13).

Kapur trees reached their optimal increment at the age of 40 years old, with the mean annual increment of 0.35 $m^3$ $ha^{-1}$ $year^{-1}$ and current annual increment of 0.36 $m^3$ $ha^{-1}$ $year^{-1}$, and total volume of 14.15 $m^3$. The graph for MAI and CAI of kapur trees is displayed in Figure 14. The graphic illustration of the relationship between the total volume and age can be seen in Figure 15.

The regression analysis for kapur trees cultivated in the first generation forest gardens indicated a linear relationship with a polynomial graph and the regression value of 99.91% (Figure 15). The seven types of trees cultivated in the first generation forest gardens had high correlation coefficients, where the average of the regression value was above 90%, which means that there was a correlation between age and total production as well as age and total revenue of each type of cultivated trees. Production simulation would be inseparable from the distribution of diameter. Even-aged forests had a distribution which was relatively normal, hence following a normal curve, in which the highest number of trees would be found in the average diameter position (Ruchaemi 2013). The relationship between the height and number of trees seemed to follow a normal distribution, however, for the uneven-aged forests, the curve would have a skewed distribution, in which the dominant trees were the ones with a small diameter; therefore the bigger the diameter, the less number of trees (Ruchaemi 2013).

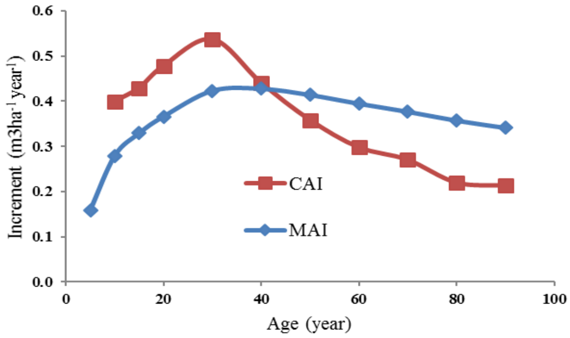


**Figure 12**. MAI and CAI of meranti (*Shorea* sp.)

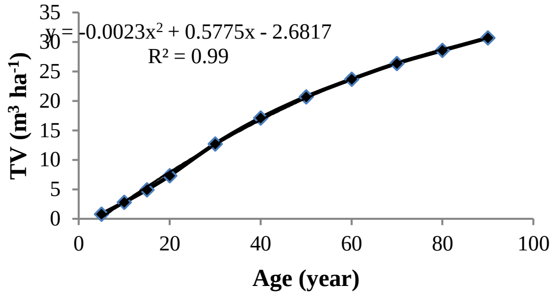


**Figure 13.** The relationship between age and total volume of meranti (*Shorea* sp.)

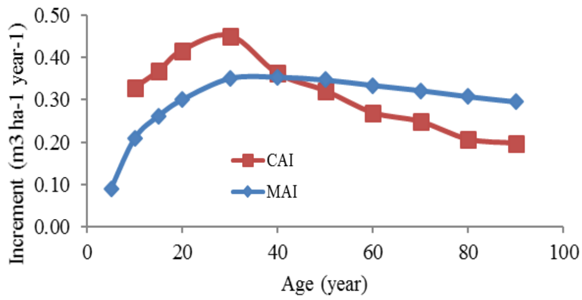


**Figure 14**. MAI and CAI of Kapur (*Dryobalanops aromatica*)

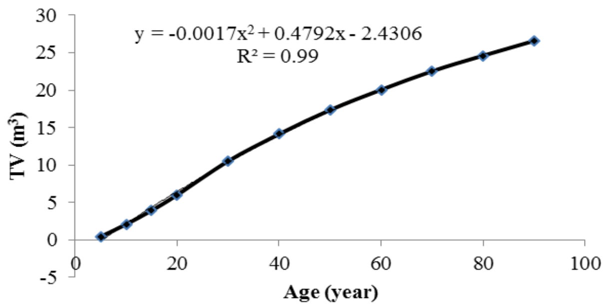


**Figure 15**. The relationship between age and total volume of kapur (*Dryobalanops aromatica*) trees

**Table 5.** The simulation of production and total revenue for rambutan (*Nephelium lappaceum*) trees cultivated in the first generation forest gardens

| Age | n | TR | AR | MR | TP |
|---|---|---|---|---|---|
| 5 | 60 | 105 | 21 | | 3500 |
| 10 | 45 | 228 | 23 | 25 | 7600 |
| 15 | 40 | 360 | 24 | 26 | 12000 |
| 20 | 35 | 420 | 21 | 12 | 14000 |
| 25 | 30 | 450 | 18 | 6 | 15000 |
| 30 | 25 | 468 | 16 | 4 | 15600 |
| 35 | 20 | 420 | 12 | -10 | 14000 |

Notes: n: number of trees $ha^{-1}$ ; TR: total revenue (x.IDR100.000); AR: Average Revenue (IDR $ha^{-1}$ $yr^{-1}$); MR: Marginal Revenue (IDR $ha^{-1}$ $yr^{-1}$); TP: Total Production

**Table 6.** The simulation of meranti (*Shorea* sp.) log production

| Age | N | D | H | TV | MAI | CAI |
|---|---|---|---|---|---|---|
| 5 | 8 | 12 | 11 | 0.80 | 0.16 | |
| 10 | 8 | 19 | 16 | 2.79 | 0.28 | 0.40 |
| 15 | 8 | 25 | 17 | 4.94 | 0.33 | 0.43 |
| 20 | 8 | 29 | 19 | 7.33 | 0.37 | 0.48 |
| 30 | 8 | 38 | 20 | 12.70 | 0.42 | 0.54 |
| 40 | 8 | 44 | 21 | 17.11 | 0.43 | 0.44 |
| 50 | 8 | 48 | 22 | 20.69 | 0.41 | 0.36 |
| 60 | 8 | 51 | 23 | 23.67 | 0.39 | 0.30 |
| 70 | 8 | 54 | 24 | 26.37 | 0.38 | 0.27 |
| 80 | 8 | 57 | 25 | 28.57 | 0.36 | 0.22 |
| 90 | 8 | 59 | 26 | 30.69 | 0.34 | 0.21 |

Notes : n: population of meranti (trees/ha); d: tree diameter (cm); h: clear bore height (m); TV: total volume ($m^3$ $ha^{-1}$); MAI: Mean Annual Increment ($m^3$ $ha^{-1}$ $yr^{-1}$); CAI: Current Annual Increment/ ($m^3$ $ha^{-1}$ $yr^{-1}$).

**Table 7.** The simulation of kapur (*Dryobalanops aromatica*) Trees Log

| Age | n | d | h | TV | MAI | CAI |
|---|---|---|---|---|---|---|
| 5 | 8 | 10 | 9 | 0.45 | 0.09 | |
| 10 | 8 | 19 | 12 | 2.09 | 0.21 | 0.33 |
| 15 | 8 | 23 | 16 | 3.93 | 0.26 | 0.37 |
| 20 | 8 | 27 | 18 | 6.02 | 0.30 | 0.42 |
| 30 | 8 | 35,5 | 19 | 10.53 | 0.35 | 0.45 |
| 40 | 8 | 41 | 20 | 14.15 | 0.35 | 0.36 |
| 50 | 8 | 45 | 21 | 17.36 | 0.35 | 0.32 |
| 60 | 8 | 48 | 22 | 20.05 | 0.33 | 0.27 |
| 70 | 8 | 51 | 23 | 22.54 | 0.32 | 0.25 |
| 80 | 8 | 54 | 24 | 24.61 | 0.31 | 0.21 |
| 90 | 8 | 56 | 25 | 26.59 | 0.30 | 0.20 |

Notes : n: population of meranti (trees/ha); d: tree diameter (cm); h: clear bore height (m); TV: total volume (m3/ha); MAI: Mean Annual Increment ($m^3$ $ha^{-1}$ $yr^{-1}$); CAI: Current Annual Increment/ ($m^3$ $ha^{-1}$ $yr^{-1}$)

Based on the definitions above, the illustration for the diameter distribution of a stand in the first generation forest gardens can be seen in Figure 16.

Meanwhile, the regression equation for the relationship between the distribution of diameter class and the frequency of the numbers of trees can be seen in Figure 17.

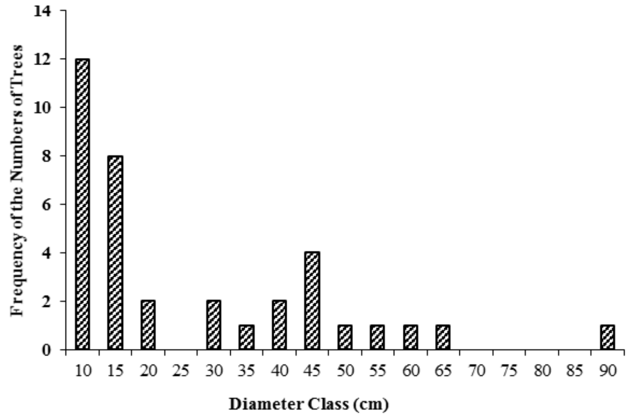


**Figure 16**. The relationship between distribution of diameter class and the frequency of the numbers of trees in the first generation forest gardens

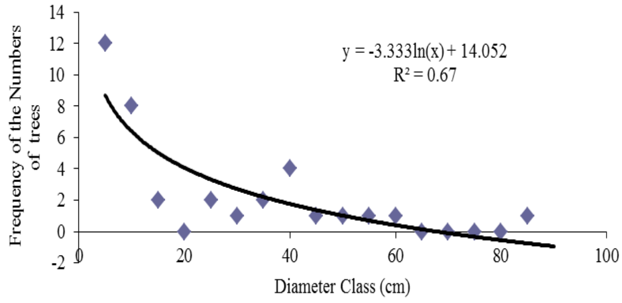


**Figure 17**. The regression equation for the relationship between the distribution of diameter class and the frequency of the numbers of trees in the first generation forest gardens

The diameter distribution in the first generation forest gardens formed skewed distribution, which indicates that the bigger the diameter of a stand, the lower the frequency of the number of trees, and vice versa: the smaller the diameter of a stand, the higher frequency of the number of trees. This statement was supported by the regression equation, in the form of a logarithm (Figure 17). The diameter distribution with a skewed distribution form was the diameter distribution form of a natural forest. After the analysis, the diameter distribution form of the forest gardens was a skewed distribution, which would belong to the natural forest characteristic, meanwhile in practice, concerning the cultivation technique implemented, the forest gardens would be considered as the plantation forest. This was caused by the human cultivation techniques of forest gardens. However, due to the long periods of cultivating (several decades), the distribution of the diameter seemed to resemble the diameter of a natural forest. This is in accordance with the report (Michon et al. 2007) that planted forests in South-east Asia and Africa can be similar to natural forests. Their vegetation structure and composition have economic value and environmental services.

**Financial feasibility analysis of forest gardens cultivation**

The cash flow of the first generation forest gardens indicated that the total cost needed to cultivate a forest gardens for 90 years would be IDR 287,510,000 and the gross income would be IDR 595,876,000. Therefore, this particular forest utilization/ cultivation had the benefit value (B/C Ratio) as much as 2.1, which meant that it would be worth implementing, since for each IDR 1000 of the cost paid, the output gained was IDR 2100.

The harvest of the first generation forest gardens products was started from the age of 1 year old to 90 years old. The rice and spice harvests would be done for a year long. Afterwards, the cultivation of vegetables namely corns, chillies and string beans, was done for two years. Then, the harvest of fruits would begin at the age of 5 years old until 90 years old, however, in between the years, there would be the harvest for meranti and kapur trees logs- until those trees were cut down at the age of 90 years old.

Based on the analysis of the net cash flow, it was found that the cultivation of the first generation forest gardens by the community was properly done, with a discount factor of 5%, Pay Back Period value obtained at the age of 19.3 years, a positive NPV as much as IDR 30,004,000. This indicated that if the cultivation of forest gardens by community was done, in 90 year-time it would be beneficial with the present value of IDR 30,004,000. In addition, the value of Net B/C Ratio was 1.58, which means that the total benefit obtained would have a surplus of 15.8% from the total cost spent. Meanwhile, the IRR was 8.8%, which indicated that the cultivation of the first generation forest gardens by the community would still be feasible at the Discount Rate level of 8.8%.

Moreover, at the discount rate of 10%, the values of NPV, Net B/C ratio and IRR were not feasible because the NPV value was negative; the Net B/C ratio was smaller than 1 and the IRR was smaller than the valid bank interest rate. Therefore, if the discount factor of 10 % was used, the cultivation of forest gardens was not feasible.

The cultivation of forest gardens (munaan) by the community began with the cultivation of varieties of rice, vegetables, fruits and timber/ logs by using traditional agricultural system namely shifting cultivation, followed by the cultivation of the first generation forest gardens which was maintained and sustained in several tens of years. The amount of income level for each fruit type such as durian, rambutan, langsat, ihau and cempedak would be different, depending on the quantity of fruit production and selling prices. Furthermore, the amount of the total income for timber produced by kapur and meranti trees would depend on the total volume of the timber/ log, based on its diameter and basal area, multiplied by the price of the timber itself. The first generation forest gardens (munaan) was feasible to be cultivated by community living in and around the forests, with the values of Pay Back Period, Net Present Value (NPV) and Net B/C of 19.3 years; IDR 30,004,000 and 1.58 respectively. In addition, the IRR value was 8.8% at the discount factor of 5%. The financial feasibility analysis of the forest gardens is hopefully useful to be a guideline for the government in making the policy to determine the extent of cultivation/ utilization scale for farmers, especially because this cultivation/ utilization scale is related to the income and welfare levels of the farmers. The cultivation of the first generation forest gardens should be continued with the second generation in order to obtain optimal economic value.

Substitution of plant species that make higher economic value not only selected naturally or ecologically, but must intervene human in restoring soil fertility. Rambutan and cempedak trees require sufficient sunlight for growth, so thinning of the sapling trees needs to be cut down. Economic turnover over the age of 45 years needs selective thinning to get enough sunlight for staple crops such as rambutan and cempedak. It is not possible for naturally occurring, so it is necessary to intervene before the age of 45 years.

The low production growth of plant biomass that produces timber is not solely influenced by modern human management, but also influenced by natural management and local management. One example of incremental timber increment will be increased if there is a thinning of fruit plants that are no longer productive. There is a tendency that the onset of thinning activities more influenced by local management wisdom deliberate, especially by those who are aged over 50 years. It is intended as a food reserve, especially fruits, medicines. Deliberate management with local knowledge compared to unintentional management. In addition there are limitations of food, because a lot of star-eaten fruit.

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