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Financial analysis of dipterocarp log production and rubber production in the forest and land rehabilitation program of Sekolaq Muliaq, West Kutai District, Indonesia

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Abstract. *Lahjie AM, Lepong A, Simarangkir BDAS, Kristiningrum R, Ruslim Y. 2018. Financial analysis of dipterocarp log production and rubber production in the forest and land rehabilitation program of Sekolaq Muliaq, West Kutai District, Indonesia. Biodiversitas 19: 757-766.* The Dayak community of East Kalimantan in the last decade has begun to develop production systems that integrate forest timber tree species into plantation commodity enterprises. They have become aware that the natural forest species of their surroundings such as Meranti (*Shorea* sp.) and Kapur (*Dryobalanops aromatica*) are often easier to exploit economically, and represent potentially cheaper investments, than are introduced plantation crops such as rubber (*Hevea brasiliensis*). This is because the price of rubber latex has decreased over the years and has ceased to give a financial return commensurate with the investment required to develop rubber as a monocrop. The research described in this paper aimed to evaluate the viability of a dipterocarp forest/rubber plantation system cultivated by people in the West Kutai District of East Kalimantan. The viability of the system was evaluated by (i) measuring its production of dipterocarp logs and natural rubber; (ii) determining the diameter distribution of its dipterocarp trees and (iii) assessing the financial feasibility of the dipterocarp/rubber system using the theories of increment production and basal area applied to the determination of Pay Back Period, Net Present Value (NPV), Net Benefit Cost (B/C) ratio and Internal Rate of Return (IRR). The research areas on which the evaluation was performed consisted of (1) a mixed population of *Shorea* spp. (Meranti) and rubber (*Hevea brasiliensis*) and (2) a mixed population of *Dryobalanops aromatica* (Kapur) and rubber. The growth analysis of *Shorea* spp. combined with rubber as well as *D. aromatica* combined with rubber at the planting distance of 5m x 5m showed that the maximum cycle was reached at the age of 40 years. Whereas the rubber trees in monoculture cultivation reached their maximum cycle at the age of 17 years. The optimum increment of MAI and CAI of *Shorea* spp. combined with rubber reached 3.61 m^3 ha^{-1} $year^{-1}$ and 3.62 m^3 ha^{-1} $year^{-1}$ respectively. The maximum increment of MAI and CAI of *Dryobalanops aromatica* combined with rubber reached 3.09 m^3 ha^{-1} $year^{-1}$ and 3 m^3 ha^{-1} $year^{-1}$ respectively.

Keywords: Dipterocarp, financial analysis, rehabilitation

INTRODUCTION

The natural resources of a country are of a vital asset in providing the foundation for the infrastructural and economic development of its people. However, development of such natural resources cannot altogether escape negative consequences for the natural environment and social well-being of communities dependent on it. Economic exploitation of natural forest resources, the conversion of forest into cultivated land, and water pollution arising from clearing of forest canopies lead to long-term environmental problems. Moreover, such land utilisation practices are often achieved at the expense of a labour force subject to poor working conditions, low wages and human rights violations (Sitepu et al. 2016). These are problems of major significance that need careful resolution.

The world requires sustainable forest management as a guarantee of safe supply of timber and of environmental services. Environmental services that result from sustainable forest management include flood buffering, carbon sequestration, wildlife habitat protection, and safe shelter for forest-dependent human populations (Canadell and Raupach 2008; Chao 2012; Putz et al. 2008; Putz et al. 2012). Forest protection of human populations is not an easy thing especially in locations where poverty prevails and cash income is minimal. Because forest timber is a very valuable cash crop commodity, in developing countries there is a strong incentive for illegal logging sponsored by timber traders. Law enforcement is often weak in such cases. (Laporte et al. 2007; Poulsen et al. 2011; Laurance et al. 2009). Apart from the direct destruction of forest caused by such illegal logging, the transport roads and skid trails made by forest companies also hinder the natural movement of wildlife in the forest, especially small animal species. That is a significant cause of ecological change (Laurance et al. 2009). For large vertebrate animals, the opening up of the forest caused by logging, makes them more vulnerable to local hunters searching for animal protein as well as to hunters from logging companies (Bennet and Gumal 2001). Guided hunting is still common, and is difficult to monitor (Meijaard et al. 2005; Poulsen et al. 2011). These hunting activities are supported by local communities and forest companies who are often involved in the live animal trade supplying wild animal protein. All these unregulated impacts on native forest ecosystems pose a severe threat to sustainable forest production from protected areas (Meijaard et al. 2005; Wilcove et al. 2013).

The proportion of trees injured because of felling activity in some concessionaires can be substantial. The amount of damage depends on the heights of the trees, the size of their crowns and the topography. Mono-cable winch systems mostly damage *Shorea johorensis* trees, followed by *Shorea assamica*, *Shorea pinanga* and *Dipterocarpus* spp., whereas bulldozer systems mostly damage *Shorea laevis*, followed by *Dipterocarpus* spp. (Ruslim 2011; Ruslim et al. 2016).

In the last decade, the Dayak community has started to develop enterprises based on combination of timber forest species with plantation commodity species. They have realized that the forest resources existing around them are easy to develop and investment in them is cheaper compared to investment in plantation production (Muliadi et al. 2017). The price received for natural rubber has been decreasing from year to year and has not been commensurate with the investment spent on plantation development.

Forests play very important roles in sustaining the environment (Görner and Seeland 2002). Forests serve various functions, such as production forest, protected forest, conservation etc. Based on the long-term forestry development strategy, the government has sought to optimize returns from unproductive forests by utilizing them for plantation forests (Prasetyo et al. 2014). This strategy has been able to attract a lot of investors because plantation forests have high economic value (benefits). Plantations are generally managed by private entrepreneurs, with the government only acting as a regulator (Anjasari 2009).

Society's need for wood tends to increase from year to year, while the stock of wood from natural sources in recent decades has been decreasing. The analysis shows the national demand for logs used in processed wood commodities such as woodworking timber, blockboard, veneer, chip wood, pulp, except plywood (Widyanto et al. 2014) increased up to the year of 2014 (the period when the analysis ended) reaching 115,633,444 m^3 $year^{-1}$. On the other hand, the stock of logs was only 13,873,734 m^3 $year^{-1}$ trending downwards. Wood product consumption will keep increasing, thus a method to reduce wood harvesting from native forest has become essential if the biodiversity of tropical forests is to be preserved (Ruslim et al. 2016).

The program of NMLR (the National Movement of Land Rehabilitation) conducted in 2005 in West Kutai District, of East Kalimantan, aimed to utilize some types of indigenous tree species - *Shorea* spp., tengkawang, mirabow wood, agarwood, durian and rambutan (Fujiki et al. 2016) - for planting on the critical land. An area of 1,061,777 ha in West Kutai District was targeted for planting in this way according to Sunandar (2005) and Kettle (2010).

The development of dipterocarp and rubber for the purpose of land and forest rehabilitation is similarly expected to give economic and ecological benefits (Majuakim and Kitayama 2013; Susanti and Maryudi 2015). These types of developments are considered to be environment-friendly. However, the cultivation of dipterocarp trees is an investment that needs a long period of time to produce an economic benefit, so it is necessary to carry out a financial analysis to see whether the investment is justified (Manuri et al. 2017; Widiyanto et al. 2014).

Thus, the research we report here had the objective of performing a financial analysis of the program of land and forest rehabilitation involving a combination of dipterocarp log production with rubber production in Sekolaq Village, West Kutai District. The research was conducted to see if this system of land-use can give economic benefits in the short-term and social and ecological benefits in the long-term. Financial investment criteria were used to assess the feasibility of further business investment in such enterprises (Osone et al. 2016).

MATERIALS AND METHODS

This research was located in Sekolaq Muliaq Village, Sekolaq Darat Sub-district, West Kutai District, East Kalimantan, Indonesia. This location was selected because since 2013 there has been a government program (Ministry of Forestry) which promoted in the area called the National Movement for Forest and Land Rehabilitation, abbreviated in the Indonesia language as GN-NMLR (Ministry of Forestry 2009). The majority of people involved in this program cultivate Meranti (*Shorea* spp.) and *Dryobalanops aromatica* (Kapur) as well as rubber as the plant species used for forest and land rehabilitation. The study sites in East Kalimantan were located at 0°15' 25.49" S - 115° 46' 30.97" E (Figure 1).

Data collection

The study site contained dipterocarp species, namely *Shorea* spp. (Meranti) and *Dryobalanops Aromatica* (Kapur), in combination with rubber at fixed planting distances (Winarni et al. 2017). Agroforestry cultivation was applied, where the *Shorea* spp. was planted together with rubber (*Hevea brasiliensis*) at the age of 3, 5, 8, 10, 20 and 25 years. The *D. aromatica* was planted together with rubber at the age of 3, 5, 8, 10, 20 and 25 years. The pattern of plant spacing of the *Shorea* spp. and *D. Aromatica* is presented below as figure 2. An area with rubber trees in monoculture cultivation was used as a comparison for test the financial feasibility of the mixed system (Florian 2014). Monoculture cultivation was planted by plant distance of 7m x 3m. The method used to collect data was systematic random sampling. Although the pattern of planting was applied for 0.5 ha land area, this study has analyzed wood and rubber production by used 1 ha land area indicator. In the field, tree stands of ages 30, 35, 40 and 45 years were not available, so their characteristics were estimated mathematically using simple linear regression (Dhakal et al. 2015).

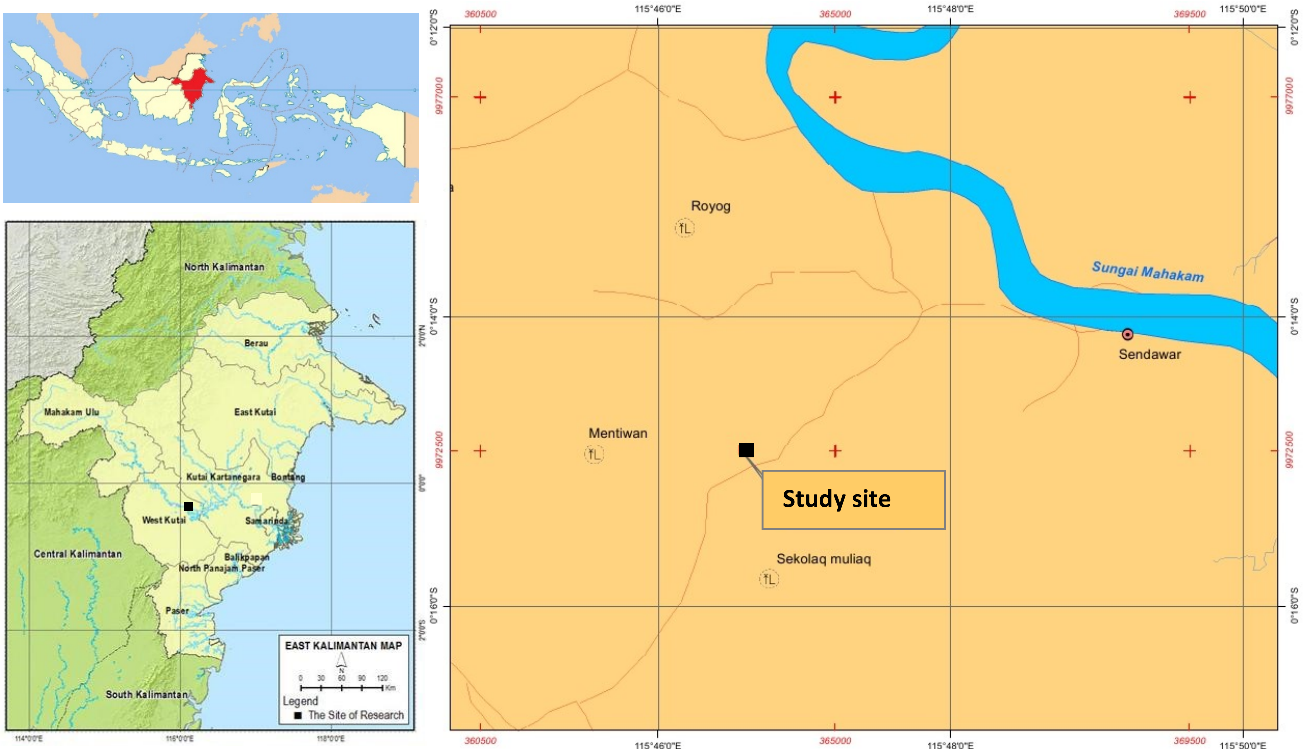

Figure 1. Location of the study site in Sekolaq Darat sub-district (■), West Kutai district of East Kalimantan, Indonesia

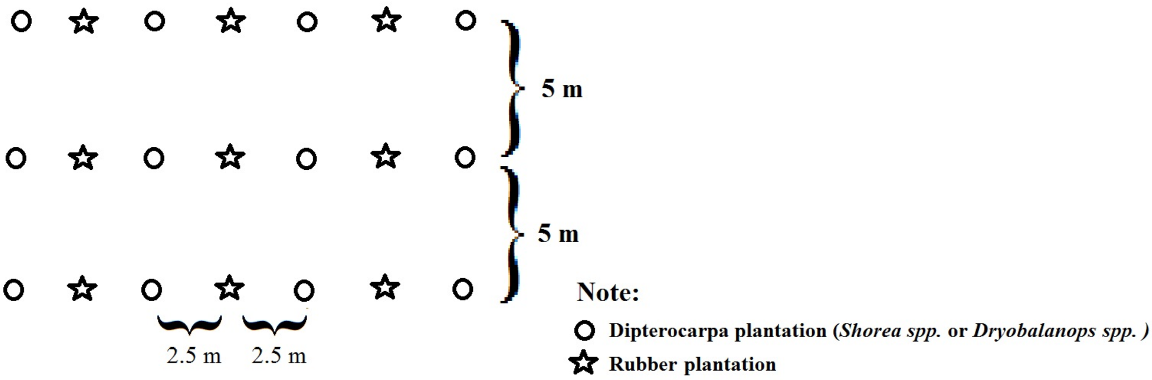

Figure 2. Pattern of planting spacing between dipterocarp and rubber plantation

Estimation of potential logs

Potential logs were calculated by measuring the circumference of the trees to estimate their diameters. The tree circumference was measured at breast height (130 cm) using a Phi-band. The tree height was measured by using clinometers without measuring the horizontal distance, with the help of a 4-meter long measuring rod placed vertically on the tree trunk (Van Gardingen et al. 2003). The tree volume was calculated using the following formula:

$$V = \frac{1}{4}\pi d^2 h t f$$

In which: V = standing volume, d = diameter at breast height (cm), h = tree height (m), f = form factor.

Other parameters for the trees were estimated according to the following formulae:

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

In which: MAI = mean annual increment, V_t= total standing volume at age t, t = tree age

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

In which: CAI = current annual increment, V_t = total standing volume at age t, V_{t-1} = total stand volume at age t-1, T = time interval between each measurement age.

$$AP = \frac{P_t}{t}$$

Where: AP =average product, P_t = total production at age t, t = tree age

$$MP = \frac{P_t - P_{t-1}}{T}$$

Where: MP = marginal product, P_t = total production at age t, P_{t-1} = total production at age t-1, T = time interval between each measurement age.

Diameter distribution of the trees was determined by frequency distribution where the highest frequency of diameter would exist around the central value (average) of the stands and the frequency would decrease to larger and smaller diameters according to a normal bell curve (Ma et al. 2016). The criteria used in evaluating the business feasibility were the parameters Net Present Value (NPV), Net Benefit/Cost Ratio (B/C), and Internal Rate of Return (Russel et al 2011; Graves et al. 2007) with the MAR value of 5%. The Internal Rate of Return (IRR) is the mean annual return derived from an investment and expressed in percentage (Graves et al. 2007). 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:

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

In which: NPV_1 = positive Net Present Value, NPV_2 = negative Net Present Value, i_1 = interest rate when NPV is positive, i_2 = interest rate when NPV is negative.

RESULTS AND DISCUSSION

The potential diameter distribution and growth over time of Meranti trees (*Shorea* spp.)

The planting distance of *Shorea* spp. cultivation was 400 trees per hectare and with 20% replanting. *Shorea* spp. trees were planted in combination with rubber stands. The results of measurement showed that the simulation of maximum production of *Shorea* spp. was reached at the age of 40 years based on their life cycle. At age 40 years, the maximum total volume (TV) would be 144.21m^3 ha^{-1}, with an average tree diameter (d) of 32 cm and a branch-free height (h) of 13 m. The estimated potential production of *Shorea* spp. trees throughout their life cycle can be seen in Table 1.

Table 1 shows that the diameter of *Shorea* spp. combined with rubber, at the ages of 10, 30 and 40 years, reached 9.4 cm; 25.5 cm and 32 cm respectively. This means that the diameter accretion decreased to 0.94 cm $year^{-1}$; 0.85 cm $year^{-1}$ and 0.80 cm $year^{-1}$ respectively.

The total volume of *Shorea* spp. at the age of 10, 30, 40 years was estimated as 9.44 $m^{3;}$ 101.08 m^3, and 144.21 m^3 respectively. The values of MAI at the age of 10, 30 and 40 years were estimated at 0.94 m^3 ha^{-1} $year^{-1}$; 3.37 m^3 ha^{-1} $year^{-1}$ and 3.61 m^3 ha^{-1} $year^{-1}$ respectively. The total volume and the increment of *Shorea* spp. increased from age 10 years to age 40 years because of its volume accretion. However, it was simulated that after the age of 40 years the growth of *Shorea* spp. would decrease. This means that the maximum increment would be achieved at the age of 40 years so that at this age, *Shorea* spp. trees would be ready to harvest.

The graph of Mean Annual Increment (MAI) and Current Annual Increment of *Shorea* spp. wood over time, based on the data in Table 1, is presented in Figure 3.

Table 1. Simulation of potential production of *Shorea* spp.

Year	n	d	h	F	TV	MAI	CAI
3	380	3	2	0.82	0.44	0.15	-
5	360	4.7	3	0.8	1.50	0.30	0.53
8	340	7.5	4.4	0.78	5.15	0.64	1.22
10	330	9.4	5.5	0.75	9.44	0.94	2.14
15	320	14	7.5	0.72	26.59	1.77	3.43
20	300	17.5	9.5	0.71	48.65	2.43	4.41
25	280	21.5	10.5	0.7	74.68	2.99	5.21
30	260	25.5	11.2	0.68	101.08	3.37	5.28
35	250	28.7	12	0.65	126.09	3.60	5.00
40	230	32	13	0.6	144.21	3.61	3.62
45	200	35	14	0.58	156.17	3.47	2.39

Note: n: the population of *Shorea* spp. (trees/ha); d: tree diameter (cm); h: branch-free height (m); f: form factor; TV: total volume (m^3 ha^{-1}); MAI: Mean Annual Increment (m^3 ha^{-1} $year^{-1}$); CAI: Current Annual Increment (m^3 ha^{-1} $year^{-1}$)

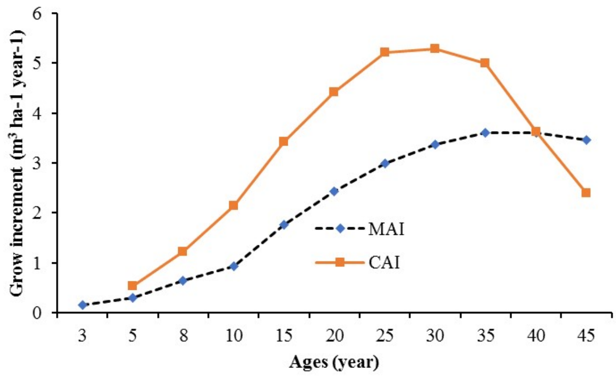

Figure 3. MAI and CAI of *Shorea* spp. wood up the age of 45 years

Table 2. Diameter distribution of *Shorea* spp. trees (combined with rubber trees) at the age of 40 years

n	d	H	TV
2	18	9	0.30
3	20	9.0	0.55
5	22	9.0	1.11
7	24	10.0	2.06
9	26	10.0	3.01
11	28	12,0	5.12
13	30	12.0	6.94
15	32	13.0	9.40
13	34	13.0	8.89
12	36	14.0	9.91
9	38	14.0	7.86
7	40	15.0	7.25
4	42	15.0	4.49
3	44	15.0	3.69
2	46	16.0	2.87

Notes : n: population of *Shorea* spp. (trees ha^{-1}); d: tree diameter (cm); h: branch-free height (m); TV: total volume (m^3 ha^{-1})

Table 3. Simulation for potential production of *Dryobalanops aromatica* trees

Y	n	d	h	f	TV	MAI	CAI
3	380	3	1.8	0.82	0.40	0.13	-
5	360	4.5	2.8	0.8	1.28	0.26	0.44
8	350	7	4.0	0.78	4.20	0.53	0.97
10	330	8.5	5.0	0.76	7.11	0.71	1.46
15	320	12.5	6.5	0.72	18.37	1.22	2.25
20	300	16.3	8.0	0.7	35.04	1.75	3.33
25	280	20	9.6	0.69	58.24	2.33	4.64
30	260	24	10.6	0.68	84.74	2.82	5.30
35	250	27	11.5	0.66	108.59	3.10	4.77
40	240	29	12.0	0.65	123.59	3.09	3.00
45	210	32	13.0	0.61	133.86	2.97	2.06

Note: n: the population of Shorea spp. (trees ha^{-1}); d: tree diameter (cm); h: branch-free height (m); f: form factor; TV: total volume m^3 ha^{-1}; MAI: Mean Annual Increment m^3 ha^{-1} $year^{-1}$; CAI: Current Annual Increment m^3 ha^{-1} $year^{-1}$

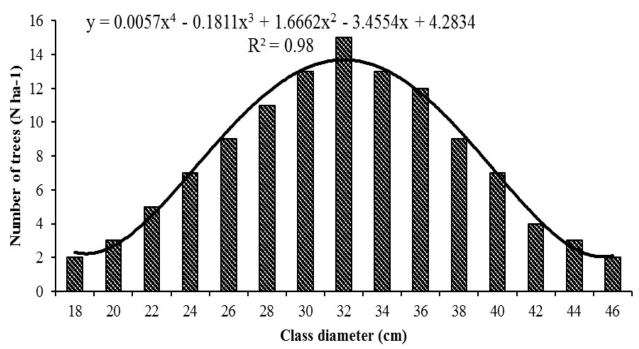

Figure 4. Diameter class distribution of *Shorea* spp. at the age 40 years

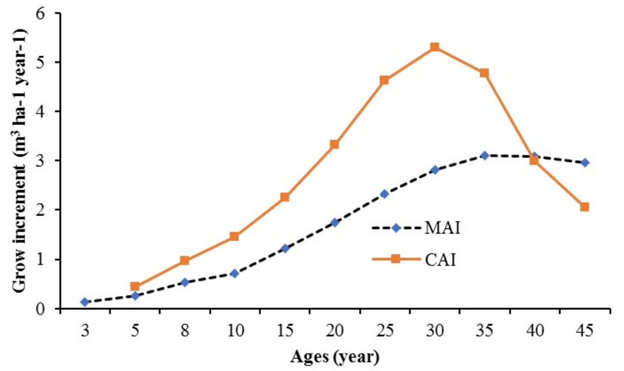

Figure 5. MAI and CAI of *D. aromatica* wood up to the age of 45

Figure 3 shows that intersection point of mean annual increment and current annual increment curves for *Shorea* spp. planted at a planting distance of 5m x 5m occurs at the age of 40 years, when the total volume per unit is 144.21 m^3 and with values for MAI and CAI of 3.61 m^3 $ha^{-1}year^{-1}$) and 3.62 $ha^{-1}year^{-1}$ respectively.

The diameter distribution for *Shorea* spp. is assumed to follow a normal curve as in a plantation forest The purpose of determining the frequency distribution for tree diameter was to simulate the spread of *Shorea* spp. diameters that would exist in the research plot at age 40 years .

Table 2 shows that the simulated diameters of *Shorea* spp. trees at the age of 40 years varied according to a normal distribution from 18 cm to 46 cm, but the highest frequency (15 trees) was in the 32 cm diameter class. Graphically, the diameter distribution of *Shorea* spp. at the age of 40 years can be seen in Figure 4.

The potential diameter distribution and growth over time of kapur trees (*Dryobalanops aromatica*)

The planting distance of *Dryobalanops aromatica* cultivation was 400 trees per hectare plus 20% replanting. *D. aromatica* was planted in combination with rubber stands. The results of a whole-of-life simulation of production of *D. aromatica* based on measurements of sampled trees at 3, 8 and 20 years of age is shown in Table 3. At age 40 years, based on the simulation of the trees life cycle, maximum total volume (TV) was estimated to be 123.59 m^3 ha^{-1} with an average tree diameter (d) of 29 cm and branch-free height of 12 m. At this age, mean annual increment (MAI) would have reached 3.09 m^3 ha^{-1} $year^{-1}$ and its current annual increment (CAI) 3.00 m^3 ha^{-1} $year^{-1}$.

Based on Table 3, the total volume of *D. aromatica* at the age of 10, 30 and 40 years would reach 7.11 m^3; 84.74 m^3 and 123.59 m^3 respectively. The value of MAI at age 10, 30 and 40 years would reach 0.71 m^3 ha^{-1} $year^{-1}$; 2.82 m^3 ha^{-1} $year^{-1}$ and 3.09 m^3 ha^{-1} $year^{-1}$. The total volume and the increment of *D. aromatica* at the age of 10 to 40 years increased because of volume accretion. However, based on Table 3, it was found that after the age of 40 years the growth of *D. aromatica* decreased so that the trees would be best harvested at this age. This can be inferred from the graphical presentation in Figure 5 where the simulated curves for Mean Annual Increment (MAI) and Mean Current Increment (CAI) intersect at age 40 years.

Table 4. Diameter distribution of *D. aromatica* trees (combined with rubber trees) at the age of 40 years

N	D	H	TV
2	15	10	0.24
4	17	10.0	0.62
6	19	10.0	1.16
8	21	10.0	1.83
10	23	11.0	3.01
12	25	11.0	4.21
13	27	11.0	5.32
14	29	12.0	7.21
12	31	12.0	6.95
10	33	12.0	6.57
9	35	12.0	6.54
7	37	13.0	6.16
6	39	13.0	5.68
4	41	13.0	4.19
3	43	13.0	3.40

Notes : n: population of *D. aromatica* (trees ha^{-1}); d: tree diameter (cm); h: branch-free height (m); TV: total volume m^3 ha^{-1}

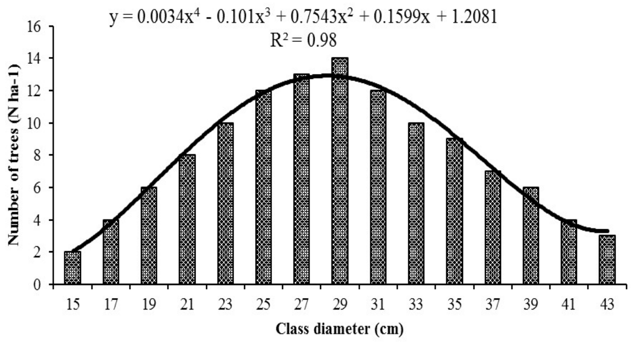

Figure 6. Diameter class distribution of *D. aromatica* at the age of 40 years

The simulated curves for MAI and CAI for *D. aromatica* trees at a plant spacing of 5m x 5m intersected at the age of 40 years when the total volume would be 123.59 m^3 ha^{-1} with MAI and CAI values of 3.09 m^3 ha^{-1} year^{-1} and 3.00 m^3 ha^{-1} year^{-1}.

The simulated tree diameter distribution of *D. aromatica* at the age of 40 years can be seen in Table 4. Table 4 shows that the simulated diameters of *D. aromatica* trees at the age of 40 years varied from 15 cm to 43 cm, but the highest frequency diameter was 29 cm. The simulated diameter distribution for *D. aromatica* at age 40 is presented graphically in Figure 6.

Production of natural rubber from a plantation interspersed with planted *Dryobalanops aromatica* trees

Rubber trees in a plantation combined with *D. aromatica* trees started to produce latex at the age of 4 years and would continue producing to age 25 years. At 4 years of age the latex production would be 170 kg and by 25 years the accumulated production would amount to 1,650 kg, with the average production per year increasing from 42.50 kg ha^{-1} year^{-1} and peaking at 82.67 kg ha^{-1} year^{-1} at age 15 years. The production of latex from the natural rubber plantation interspersed with *D. aromatica*, from year 4 through to year 25, can be seen in Table 5.

Table 5. The production of latex from rubber trees cultivated in combination with *D. aromatica*

Ages	TP (kg ha^{-1})	AP (kg ha^{-1} year^{-1})	MP (kg ha^{-1} year^{-1})
4	170	42.50	-
7	400	57.14	76.67
10	660	66.00	86.67
13	1000	76.92	113.33
15	1240	82.67	120.00
17	1400	82.35	80.00
20	1550	77.50	50.00
25	1650	66.00	20.00

Notes: TP: Total production (kg ha^{-1}); AP: Average Production kg ha^{-1} year^{-1}; MP: Marginal Production/current annual production (kg ha^{-1} year^{-1})

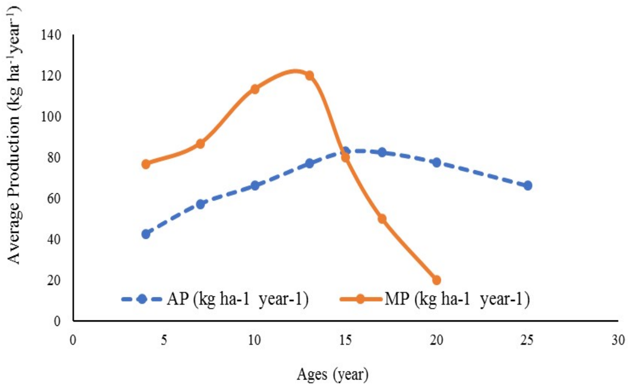

Figure 7. The latex production of rubber plantation combined with *D. aromatica*

Table 5 indicates that rubber trees were able to produce latex from the age of 5 to 25 years with the accumulated production rising from 170 to 1.650 kg across that period. Average latex production per year reached its maximum production at the age of 17 years with accumulated production of 1,400 kg, with the average production and average current annual production was 82.67 kg ha^{-1} year^{-1} and 80 kg ha^{-1} year^{-1} respectively. Rubber trees continued to produce until the age of 25 years, but the annual production of latex decreased well before this. This can be seen from the average production and the average current annual production of rubber plantation at the age of 25 which had fallen to 66 kg ha^{-1} year^{-1} and 20 kg ha^{-1} year^{-1} respectively.

Graphically, the production of latex from rubber trees cultivated in plantation in combination with *D. aromatica* trees can be seen in Figure 7.

Production of natural rubber from a plantation interspersed with planted *Shorea* spp. trees

Rubber trees combined in plantation with *Shorea* spp. started to produce latex at the age of 4 years and continued until 25 years of age. The accumulated latex production at 4 years of age was 125 kg and rose to 1,450 kg at 25 years, with the average annual production rising from 31.25 kg ha^{-1} year^{-1} at 4 years to 70.57 kg ha^{-1} year^{-1}at 25 years of age. The production of latex across the life cycle from 4 to 25 year of age can be seen in Table 6.

Table 6. Production of rubber plantation/latex cultivated in a combination with *Shorea* spp.

Ages	TP (kg ha^{-1})	AP (kg ha^{-1} yr^{-1})	MP (kg ha^{-1} yr^{-1})
4	125	31.25	-
7	320	45.71	65.00
10	550	55.00	76.67
13	850	65.38	100.00
15	1060	70.67	105.00
17	1200	70.59	70.00
20	1330	66.50	43.33
25	1450	58.00	24.00

Notes: TP: Total production (kg ha^{-1}); AP: Average Production (kg ha^{-1} year^{-1}); MP: Marginal Production/ current annual production (kg ha^{-1} year^{-1})

Table 7. Production of latex from a monoculture rubber plantation

Ages	TP (kg ha^{-1})	AP (kg ha^{-1} yr^{-1})	MP (kg ha^{-1} yr^{-1})
4	440	110.00	-
7	850	121.43	136.67
10	1350	135.00	166.67
13	2000	153.85	216.67
15	2470	164.67	235.00
17	2800	164.71	165.00
20	3100	155.00	100.00
25	3300	132.00	40.00

Notes: TP: Total production (kg ha^{-1}); AP: Average Production (kg ha^{-1} year^{-1}); MP: Marginal Production/current annual production (kg ha^{-1} year^{-1})

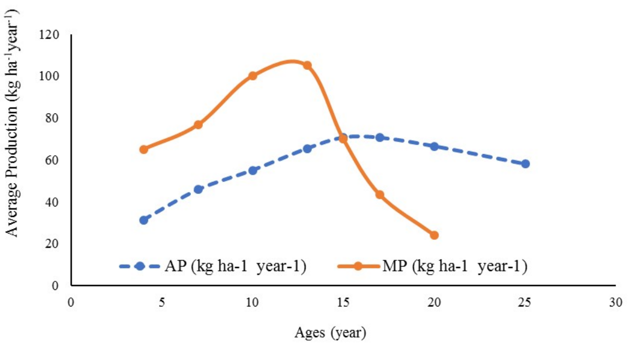

Figure 8. The latex production from rubber trees planted in combination with *Shorea* spp.

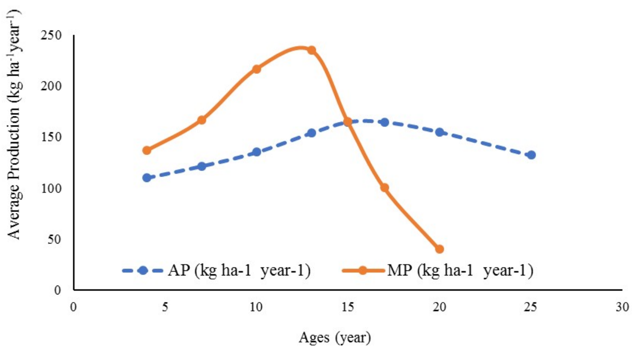

Figure 9. Production of latex from a monoculture rubber plantation

The maximum production of rubber plantation was reached at the age of 17 years with the total production of 1,200 kg and with average production and average current annual production reached 70.59 kg ha^{-1} year^{-1} and 70 kg ha^{-1} year^{-1} respectively. However, rubber trees continued to produce until the age of 25 years although the annual production declined after age 15-17 years.

The production of latex by rubber trees cultivated in combination with *Shorea* spp. is depicted graphically in Figure 8.

The production of latex from a monoculture rubber plantation

Rubber trees in monoculture started to produce latex at the age of 4 years and the optimum production was reached at age 17 years. A summary of latex production from the rubber plantation can be seen in Table 7.

Table 7 shows that 440 kg of latex was produced from monoculture rubber trees up to the age of 4 years and production continued through to 25 years of age at which time accumulated latex production had reached 3,300 kg. Graphically, the production of latex from a monoculture rubber plantation can be seen in Figure 9.

Latex started to be produced at the age of 4 years with the average production of 110 kg ha^{-1} year^{-1}. At the age of 10 years, the average annual production and average current annual production reached 135 kg ha^{-1} year^{-1} and 166.67 kg ha^{-1} year^{-1} respectively. The optimum production was reached at the age of 17 years when accumulated production had reached 2,800 kg, and the average annual production and average current annual production were 164.71 kg ha^{-1} year^{-1} and 165 kg ha^{-1} year^{-1}, respectively. However, after the age of 17 years, the average annual production and average current annual production declined as can be seen in the above AP and MP graph. The declining trend in annual productivity continued through to age 25 years.

For comparison, the accumulated rubber productivity up to optimum age in Sekolaq Muliaq Village, West Kutai, in East Kalimantan is 2.8 ton ha^{-1}, which is 9.4% lower than the optimum productivity in Dusun Sanjan, District Sanggau, in West Kalimantan (Winarni et al. 2018). Furthermore, rubber plantation not always showed similar productivity of latex for another location. Due to the factors of land fertility, precipitation and population trees, the production of latex in Galeo Asa Village reached 3 ton ha^{-1}, which is showed 20% higher than Sekolaq Muliaq Village (Lahjie et al, 2018).

Financial analysis of dipterocarp trees production in combination with latex production from rubber trees in a mixed plantation

Detailed costs needed for modeling the mixed dipterocarp/natural rubber plantation for a 40-year cycle were estimated based on local prices. The commodity prices needed for the modeling were set as follows: the value of dipterocarp wood based on the current market price and the price received at the research location ranged from Rp. 2,300,000 m^{-3} to Rp. 2,800,000 m^{-3}; the price received for natural rubber latex was Rp. 5,000 kg^{-1}. Additionally, this study used Indonesian currency, Indonesian rupiah (IDR) which is currency, 1 equal to IDR 12,000.

Based on these current market prices of wood and rubber, the income that could be obtained from each of three types of plantation is outlined in the cash flows, as follows:

Financial analysis of the combined Shorea spp.*/rubber plantation*

The simulated cash flow from *Shorea* spp. tree cultivation with a 40-year cycle and from rubber with a 25-year cycle showed that the total costs over a 40-year period were Rp. 243,577,000, while the gross income amounted to Rp. 715,93,000. Without calculating the time value of money, we estimate that this business model would result in a benefit/cost ratio (B/C ratio) of 2.9.

We simulated the effects of harvesting *Shorea* spp. wood at the age of 30, 35 and 40 years. A harvest of *Shorea* spp. trees at age 30 years and 35 years are regarded as a thinning harvest or intermediate harvest, while at age 40 it would be regarded as a total harvest with a wood price of Rp. 2,800,000 m^{-3}. Only 90% of the wood can be sold as intact usable timber, while the remaining 10% is categorised as firewood. The income obtained from *Shorea* spp. wood aged 30, 35, and 40 years with a total volume of 25.01 m^3, 18.21 m^3, and 144.21 m^3 respectively, would be Rp. 56,272,500 ha^{-1}, Rp. 40,770,000 ha^{-1}, and Rp. 324,472,500 ha^{-1} respectively. The income obtained from firewood with a price of Rp. 100,000 m^{-3} and at the age of 30, 35 and 40 years would be Rp. 477,000, Rp. 150,000, and Rp. 1,236,000, respectively. The total income obtained from rubber harvested from age 4 years to 25 years would amount to Rp. 67,600,000 ha^{-1}.

Based on these values, the financial analysis of *Shorea* spp. cultivated together with rubber, based on an interest level of 5%, reveals estimates for the Pay Back Period of 20.1 years, Net Present Value (NPV) of Rp. 58,999,000 ha^{-1}, and a Net B/C ratio of 2.79. The model analysis of Internal Rate of Return (IRR) gave a value of 8.7%.

The results of this analysis based on a 40-year plantation cycle and an interest rate of 5%, indicating that *Shorea* spp. trees cultivated in combination with rubber is a feasible business, because its estimated NPV was positive. In addition, the net B/C ratio for the business was estimated at 2.79, which means that for every rupiah invested there would be a return of 2.79 rupiahs; i.e. the value of the Net B/C > 1, indicating that the business should be profitable. The value of its IRR (8.7%) was higher than the Minimum Acceptability Rate (MAR) of 5%.

Financial analysis of the combined D. aromatica */ rubber plantation*

The simulated cash flow from *D. aromatica* tree cultivation with a 40-year cycle and from rubber with a 25-year cycle showed that the total costs over a 40-year period were Rp. 233,619,000 ha^{-1}, while the gross income amounted to Rp. 649,951,000 ha^{-1}. Without calculating the time value of money, we estimate that this business model would result in a benefit/cost ratio (B/C ratio) of 2.8.

We simulated the effects of harvesting *D. aromatica* wood at the at the age of 30, 35, and 40 years. A harvest of *D. aromatica* trees at age 30 years and 35 years is regarded as a thinning harvest or intermediate harvest, while at age 40 years it would be regarded as a total harvest with a wood price of Rp. 2,300,000 m^{-3}. Only 90% of the wood can be sold as intact usable timber, while the remaining 10% is categorised as firewood. The income obtained from *D. aromatica* wood aged 30, 35 and 40 years with the total volume of 23.85 m^3, and 123.59 m^3 respectively, would be Rp. 49,369,500, Rp. 31,050,000 ha^{-1}, and Rp. 255,831,000 ha^{-1} respectively. The income obtained from firewood at the age of 30, 35 and 40 would be Rp. 239,000 ha^{-1}, Rp. 150,000 ha^{-1} and Rp. 1,236,000 ha^{-1} respectively. While the total income derived from rubber harvested from 4 to 25 years would amount to Rp. 79,000,000.

Based on these values and an interest rate of 5%, the financial analysis of *D. aromatica* cultivated in combination with rubber reveals estimates for the Pay Back Period of 18 years, Net Present Value (NPV) of Rp. 54,827,000 ha^{-1}, and a Net B/C ratio of 2.68. The model analysis of Internal Rate of Return (IRR) gave a value of 8.8%.

The results of this analysis based on a 40-year plantation cycle and an interest rate of 5%, indicate that *D. aromatica* trees cultivated in combination with rubber are a feasible business, because the estimated NPV was positive. In addition, the net B/C ratio for the business was estimated at 2.68, which means that for every rupiah invested there would be a return of 2.68 rupiahs; i.e. the value of the Net B/C > 1, indicating that the business should be profitable. The value of its IRR (8.8%) was higher than the Minimum Acceptability Rate (MAR) of 5%.

Financial analysis for a rubber plantation as a monoculture

The simulated cash flow from a monoculture rubber plantation with a 25-year cycle showed that the total costs over a 25-year period were Rp. 174,414,000 ha^{-1}, while the gross income amounted to Rp. 232,469,000 ha^{-1}. Without estimating the time value of money, we estimated the benefit/cost ratio (B/C ratio) of this business would be 1.3. This means that for every Rp. 1.0 spent the total return would be Rp.1.3.

Rubber tapping started at the age of 4 years and continued until 25 years. The estimated accumulated income obtained from rubber harvesting through to age 25 years amounted to Rp. 158,700,000 ha^{-1} which would be the total income derived from selling the rubber latex at a price of Rp. 5,000 kg^{-1}.

Based on these values and an interest rate of 5%, the financial analysis for monoculture rubber reveals estimates for the Pay Back Period of 17.4 years, Net Present Value (NPV) of Rp. 3,240,000 ha^{-1} and a Net B/C ratio of 0.93. The model analysis of Internal Rate of Return (IRR) gave a value of 4.6%.

These results show that at an interest rate of 5%, monoculture rubber cultivation was not a financially profitable business, because its IRR value (4.6%) was lower than Minimum Acceptability Rate (MAR) of 5%.

Table 8. Recapitulation of financial analyses for the three plantation models based on rubber trees alone or in combination with either logged *Shorea* spp., or logged *D. aromatica* trees

Models	Cycle	PP	NPV	Net B/C	IRR
Shorea spp. + Rubber	40 year	20.2 year	58,999,000	2.79	8.7
D. aromatica + Rubber	40 year	18.0 year	54,827,000	2.68	8.8
Monoculture Rubber Plantation	25 year	17.4 year	3,240,000	0.93	4.6

Notes: PP: pay back period (years); NPV: net present value (Rp.); IRR: Internal Rate of Return (%)

Comparison of the financial analyses for the three plantation business models

Table 8 summarises the results of the financial analyses for the three plantation models based on rubber trees alone or in combination with either logged *Shorea* spp., or logged *Dryobalanops aromatica* trees.

The results summarised in Table 8 show that both models of dipterocarp cultivation (*Shorea* spp. or *D. aromatica*) combined with rubber were feasible businesses because the results of their financial analysis indicated that their NPV estimates were higher than zero; their Net B/C ratios were greater than 1.0; and they had positive values for IRR (higher than the value of MAR = 5%). The result of the financial analysis for monoculture rubber cultivation showed that its IRR was 4.6l% which means that it was not a feasible business proposition because its IRR was smaller than the MAR (Minimum Acceptability Rate) of 5%.

Today, rubber plantation activity has reached 72% in marginal land areas with low productivity (Ahrends et al. 2015). These land conversion trends have continued in line with apparent demand for natural rubber and palm oil (Warren-Thomas et al. 2015). Nevertheless, from our study, it would appear that at least in the case of monoculture rubber plantations, the economic rewards are poor at current latex prices.

Various models of silviculture for timber production appear to offer greater rewards. SILFOR researchers (using individual tree-based models) conducted silvicultural research techniques outside logging areas in Central Kalimantan, aiming to determine projected harvesting periods for different species compositions based on the dynamics of biomass change in selective logging (Ruslandi et al. 2017). The applied silviculture techniques are expected to be able to create better results in logged areas, especially on residual stands that can be harvested in 25-40 years (Ruslandi et al. 2012; Shenkin et al. 2015). However, the applicable logging rules are for a minimum cutting diameter (MCD) between 40 to 50 cm with shortened cutting cycle from 35 to 30 years (Ministry of Forestry 2009).

Deforestation from natural forest conversion to rubber plantations results in reductions in living biomass, in carbon sequestration above ground, and in soil organic carbon (Blagodatsky et al. 2016; De Blecourt et al. 2013; Guillaume et al. 2015; Li et al. 2008). The conversion of natural forests into rubber plantations reduces soil CO_2 emissions and CH_4 absorption, especially during very wet periods. This change has an impact on converted land, especially on the process of carbon fluctuations from the soil, thereby reducing the positive feedback from climate change.

Given the vast extent of rubber plantations (Lang et al. 2017), the last three decades have begun to see changes, with indigenous peoples trying gradually to replant native species, replacing the rubber tree plantings. This method is considered capable of stabilizing local economies, by planting native species that produce timber for the construction of homes and by planting species in canopy openings that produce non-timber forest products (NTFP). Among the most valuable NTFP's are rattans (*Calamus* spp.), sugar palm (*Caryota urens)* and medicinal *Coscinium fenestratum* (Ashton et al. 2014).

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