CHAPTER 9

Growth performance of *Calophyllum inophyllum* in bioenergy trial plots in Bukit Soeharto Forest, East Kalimantan

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Abstract: The Government of Indonesia has committed to providing its entire population with energy through the National Energy Policy, which highlights the importance of diversification, environmental sustainability, and enhanced deployment of domestic energy resources. The contribution of new and renewable energy (NRE) to the nation's energy supply is mandated to reach 23% by 2025, with bioenergy an important NRE alternative. If developed and deployed appropriately, bioenergy plantations have potential to restore degraded land and enhance biodiversity and environmental services while supporting rural livelihoods. As a potential biofuel tree species suited to the tropics, *Calophyllum inophyllum* (*nyamplung*) is being tested across wide-ranging degraded forest conditions in Indonesia. *Nyamplung* is a potential biodiesel alternative as it grows well in harsh environmental conditions, produces non-edible seed oil, has high amounts of kernel oil and fruits profusely. Here we report growth performance in plantation trial plots established in February 2018, on previously burned land in Mulawarman University's Bukit Soeharto Research and Educational Forest. Growth of this two-year-old plantation is strong compared to other Indonesian sites, with average survival rate above 90% on Ultisol soil, which is classified as low fertility and acidic. The findings reveal that different doses of fertilizer applications and slope gradient have no significant effects on growth performance. In addition, trees have already started to flower and fruit, and are colonized by bird species and insects, including bees and butterflies. The study indicates that *nyamplung* adapts well to different land and soil types. Bioenergy plantations on degraded land are a promising approach for land restoration, and enhance native biodiversity and environmental services while providing a source of renewable energy.

Keywords: *Calophyllum inophyllum*, *nyamplung*, bioenergy, degraded land, growth performance, biodiversity, East Kalimantan
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9.1 Introduction

The Government of Indonesia has committed to providing its entire population with access to modern energy sources through its National Energy Policy (*Kebijakan Energi Nasional*), a document which highlights the importance of diversification and environmental sustainability, along with enhanced supply and deployment of domestic energy resources. These diversified energy sources include coal, oil, gas and new renewable energy (NRE). The contribution of NRE to the nation's energy supply is mandated to reach 23% by 2025 (GoI 2014). Bioenergy features as an important NRE alternative in the policy. To further the development of biofuel, the Ministry of Environment and Forestry (MoEF) has been assigned an important role in terms of providing unproductive forestland (GoI 2006a, 2006b). Based on recent MoEF data, 14 million hectares (ha) of Indonesian land is unutilized and classified as 'degraded', with the government earmarking it for conversion to plantations, energy production and infrastructure (MoEF 2018).

Calophyllum inophyllum, known locally as *nyamplung*, is one potential species able to produce bioenergy, especially for biodiesel, as it meets US and European Union biodiesel standards (Atabania et al. 2011). In addition, the resulting biodiesel has a higher calorific value compared to other energy species, such as jatropha, *Pongamia pinnata* and others (Arumugam and Ponnusami 2019). Further, *Calophyllum inophyllum* biodiesel can replace fossil diesel without any need for engine modification (Ong et al. 2011). The species produces non-edible seeds with significant amounts of kernel oil, and seeds can be harvested repeatedly from the age of four to five years until trees are 50 years old (Leksono et al. 2014a). *Nyamplung* flowers attract honeybees and are a great source of honey (Leksono et al. 2019; Rahman et al. 2019). The species can also be grown alongside a variety of agricultural crops, such as maize, soybean and rice, which provides an opportunity to apply climate smart agroforestry practices (Rahman et al. 2019).

Generally, *nyamplung* grows well in warm temperatures in wet or moderate conditions. It can grow in a wide range of soils, but grows best in sandy, well-drained soils in coastal areas. It is tolerant to wind, salt spray, drought and brief periods of waterlogging. It grows at altitudes of up to 500m, where annual rainfall ranges between 1,000 mm and 5,000 mm, and annual temperatures range from 7–18°C to 37–48°C (Friday and Okano 2006). In Indonesia, it has very wide natural distribution, from Sumatra in the west to Papua in the east, and from Java in the south to Kalimantan in the north. The plant is also tolerant to harsh environmental conditions, and requires little care and maintenance when it comes to cultivation (Leksono et al. 2017). In natural stands, *nyamplung* seed can have a crude *Calophyllum* oil (CCO) content of up to 58% (Leksono et al. 2014b). In line with the breeding strategy for biofuel yielding *nyamplung* (Leksono and Widyatmoko 2010), tree populations were selected from Gunung Kidul District, where trees produced the highest CCO content (50%–50.72%) among six *nyamplung* populations from Java, and were planted in Wonogiri District in Central Java to establish a provenance seed stand. A provenance seed stand is an area where a potential provenance or land race is established and managed intensively and entirely for seed production (Zobel and Talbet 1984). Through the above breeding programme, oil content was increased by 14%–19% (Leksono et al. 2019).

Despite the species having potential for biofuel production from non-edible oil, there are limited studies into the adaptability and suitability of *nyamplung* to different locations in Indonesia. This paper aims to communicate early findings relating to *nyamplung* growth performance on previously burned degraded land in East Kalimantan.

9.2 Material and methods

9.2.1 Study site

The study site is located at Mulawarman University's Bukit Soeharto Research and Education Forest (KHDTK HPPBS) in Kutai Kartanegara District, East Kalimantan (Figure 1). This 20,271-hectare area of forestland is a part of the Bukit Soeharto Great Forest Park (*Tahura*) and was assigned to Mulawarman University by the Ministry of Environment and Forestry (MoEF) as a special purpose forest estate (KHDTK) in 2014. Site characteristics of the trial plots in Bukit Soeharto and the provenance seed stand in Wonogiri (the source of *nyamplung* seeds for the trial plots) are shown in Table 1.

The soil in the study site is classified as Ultisol (formerly red-yellow podzolic), a soil with lower base status, which is more acidic in reactions than Oxisols. It has been formed from more acidic parent materials (like dacitic and liparitic tuffs) and is rich in quartz (Tan 2008).

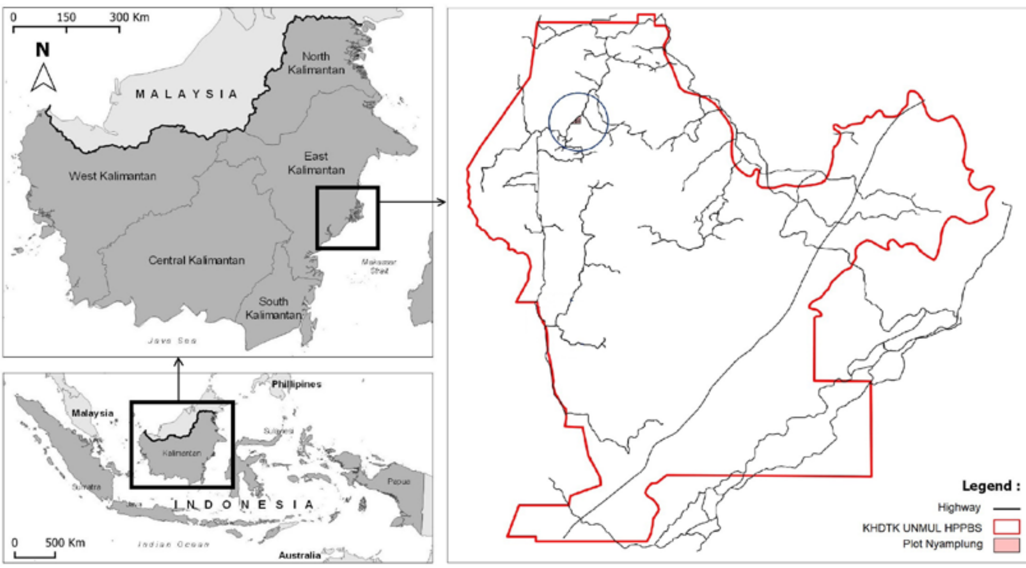

Figure 1. Location of the study site – Mulawarman University's Bukit Soeharto Research and Education Forest, East Kalimantan

Source: Map created by CIFOR, 2020

Table 1. Characteristics of the previously burned *Calophyllum inophyllum* (*nyamplung*) plantation trial plots in Bukit Soeharto Forest, East Kalimantan and the provenance seed site in Wonogiri, Central Java

Site characteristics	Bukit Soeharto	Wonogiri
Total area	20,271 ha	93.34 ha
Latitude (South)	00°47’47.5”	7°32’ – 8°15’
Longitude (East)	117°01’15.3”	110°41’ – 111°18’
Rainfall (mm/year)	2,000–2,500	1,878
Temperature (°C)	20 – 36	20 – 38
Altitude (m asl.)	117	141
Soil type	Ultisol	Vertisol
Last burned	2016	Never burned
Vegetation cover	Acacia, bamboo, scrub	Bamboo, *Dalbergia*, scrub

The area has experienced frequent fires since the late 1990s, with the last fire prior to the experiment being in 2016. Such fires lead to degradation of the forest and land, which is visually apparent from the species dominating the area, i.e., unplanted *Acacia mangium*, wild bamboo and scrub.

9.2.2 Research design and materials

The trial plot was established on a five-hectare area of the study site in early 2018 to examine the suitability of energy production tree species to degraded (previously burned) mineral soil. The trial plot was divided into five subplots with different slope gradients (see Figure 2). In February 2018, the plots were planted using genetic material from the *nyamplung* provenance seed stand in Gunung Kidul, Yogyakarta. This *nyamplung*, planted in a forest managed by the Center for Forest Biotechnology and Tree Improvement Research and Development (CFBTIRD), was found to have the highest crude *Calophyllum* oil (CCO) content of six *nyamplung* populations in Java (see Table 2).

Table 2. Crude *Calophyllum* oil (CCO) content of six provenance tree populations in Java

No.	Provenance/Land race	Dry seeds (kg)	Residual waste (kg)	CCO (kg)	CCO (%)
1.	Banyuwangi (East Java)	2.09	1.20	0.89	42.58
2.	Gunung Kidul (Yogyakarta)	2.10	1.08	1.02	48.57
3.	Purworejo (Central Java)	1.90	1.04	0.87	45.79
4.	Cilacap (Central Java)	2.10	1.25	0.85	40.48
5.	Ciamis (West Java)	2.00	1.20	0.80	40.00
6.	Pandeglang (Banten)	1.81	1.16	0.67	37.02

Source: (Leksono et al. 2014b)

Figure 2. Plot design for the *nyamplung* trial plots at Bukit Soeharto Research and Education Forest

The trial plots were arranged in a completely randomized design to examine responses of different NPK fertilizer doses and different slope gradients with the same doses. Two thousand *nyamplung* seedlings were planted with a spacing of 5 m x 5 m, aiming to allow space for the species to grow in width, given the main objective was to obtain seeds for oil production. The plots were divided into 15 permanent measurement plots (PMPs) with three replications for each plot. Two hundred and twenty-seven seedlings were randomly selected for regular measurement. Three different doses of NPK fertilizer were applied on different plots to examine growth performance: 50 g, 100 g and 200 g (Figure 3). Plot 1 and Plot 5 were given 100-gram and 200-gram doses of NPK respectively, while 50-gram doses were applied on plots 2, 3 and 4. The plots were monitored every three months between August 2018 and December 2019, with height, diameter and number of branches measured as growth parameters. Soil samples were collected from each plot with tree replication and analysed to examine soil fertility.

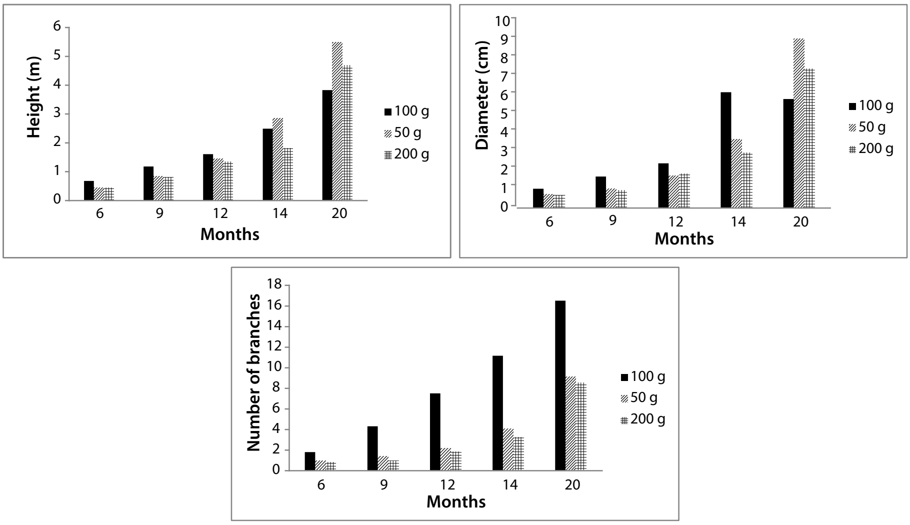

Figure 3. Mean growth performance after three different doses of NPK fertilizer

9.2.3 Data analysis

The trial plots were established with a two-way ANOVA statistical model to: i) examine the response of species growth after different treatments; and ii) examine the effect of slope gradient on species growth, regardless of treatment. Such two-way ANOVA analyses are commonly used to compare the effects of different treatments between two populations (Steel and Torrie 1980).

ANOVA was performed using the plots' mean data (Y_{ijk}) for growth, with the following linear model:

$$Y_{ijk} = m + T_i + P_j + e_{ijk}$$

where, m is the overall mean, T_i is the i-th treatment effect, P_j is the effect on the permanent measurement plot, and e_{ijk}. is the experimental error for Y_{ijk}.

An SAS (Statistical Analysis System) ver. 9.0 program was used to analyse the data.

9.3 Results and discussion

9.3.1 Results

Growth performance

Plant survival rate is one of the common parameters by which the health of plants is measured; it is dependent on environmental stress (Montenegro et al. 2013). First-year survival of transplanted seedlings plays a crucial role in the subsequent success of plantations (Sukhbaatar et al. 2020). Table 3 shows that at 20 months, the survival rate for seedlings in the trial plots was above 90%, varying between 91.1 (Plot 3) and 98.1 (Plot 2). These survival rates, however, tended to decline

Table 3. Survival rates of *nyamplung* under different treatments (i.e., NPK fertilizer doses and slope gradients)

Treatments	Survival rate (%)				
	6 months	9 months	12 months	14 months	20 months
Plot 1	93.8	91.7	91.7	91.7	91.7
Plot 2	100.0	100.0	100.0	100.0	98.1
Plot 3	100.0	100.0	97.8	93.3	91.1
Plot 4	100.0	97.8	95.6	95.6	95.6
Plot 5	97.8	97.8	97.8	97.8	95.6

after the seedlings reached 20 months old, particularly in Plot 3 where the rate declined almost 9% within 1.5 years.

Doses of NPK fertilizer

Different fertilizer doses resulted in differing growth characteristics (height, diameter, number of branches) in *nyamplung* seedlings in the trial plots (Table 4 and Figure 3). At the time of monitoring, there were no significant differences between plots and PMPs in terms of height. Height ranged from 0.8–1.2 m at nine months old and 3.8–5.5m at 20 months old. Likewise, treatments resulted in no significantly different effects on diameter growth between plots and PMPs, except at six months old. Diameter ranged between 0.7–1.0 cm and 5.9–9.1 cm at six and 20 months old, respectively. Analysis revealed that different treatments resulted in significantly different effects on the numbers of branches between

Table 4. Variance analysis of *nyamplung* growth performance after three different doses of NPK fertilizer

Source of variation	df	Mean square				
		6 months	9 months	12 months	14 months	20 months
1. Height						
Fertilizer	2	0.054**	0.134 ns	0.053 ns	0.818 ns	2.043 ns
PMP	2	0.069**	0.228*	0.489 ns	0.628 ns	0.403 ns
Error	4	0.002	0.027	0.412	2.086	9.252
2. Diameter						
Fertilizer	2	0.123 *	0.479 ns	0.387 ns	8.891 ns	6.399 ns
PMP	2	0.120 *	0.887 ns	3.118 ns	6.935 ns	12.785 ns
Error	4	0.040	0.310	1.091	19.983	10.441
3. Number of branches						
Fertilizer	2	0.836 **	9.994 **	30.434 **	57.221 **	50.692 ns
PMP	2	0.553 **	5.739 *	17.167 **	26.925 **	36.882 ns
Error	4	0.009	0.469	0.290	0.667	8.292

Remarks: df = degree of freedom; ns = non-significant; * = significant difference at 0.05 level; ** = significant difference at 0.01 level; PMP = permanent measurement plot plots and PMPs after six months old. The number of branches ranged from 0.8–1.8 at 6 months old and 8.5–16.5 at 20 months old. At the time of monitoring, a dose of 100 g of fertilizer gave the best results in terms of the number of branches.

Effects of slope gradient

Slope conditions showed no significant effects on growth performance between plots and PMPs until the age of 20 months, except in terms of diameter (Table 5, Figure 4).

Table 5. Variance analysis of *nyamplung* growth performance under three different slope conditions

Source of variation	df	Mean square				
		6 months	9 months	12 months	14 months	20 months
1. Height						
Slope	2	0.001^{ns}	0.068^{ns}	0.334^{ns}	1.328^{ns}	6.098^{ns}
PMP	2	0.058 *	0.273 *	1.689 *	4.349^{ns}	11.739^{ns}
Error	4	0.006	0.031	0.173	0.761	2.474
2. Diameter						
Slope	2	0.001^{ns}	0.019^{ns}	0.179^{ns}	0.505^{ns}	8.190 **
PMP	2	0.148 *	2.061 **	7.217 **	14.697 **	27.577 **
Error	4	0.014	0.007	0.058	0.251	0.001
3. Number of branches						
Slope	2	0.026^{ns}	0.277^{ns}	0.845^{ns}	2.086^{ns}	0.153^{ns}
PMP	2	0.490 **	3.229^{ns}	9.279^{ns}	20.718^{ns}	49.407^{ns}
Error	4	0.017	0.649	1.691	3.838	14.949

Remarks: df = degree of freedom; ns = non-significant; * = significant difference at 0.05 level; ** = significant difference at 0.01 level; PMP = permanent measurement plot

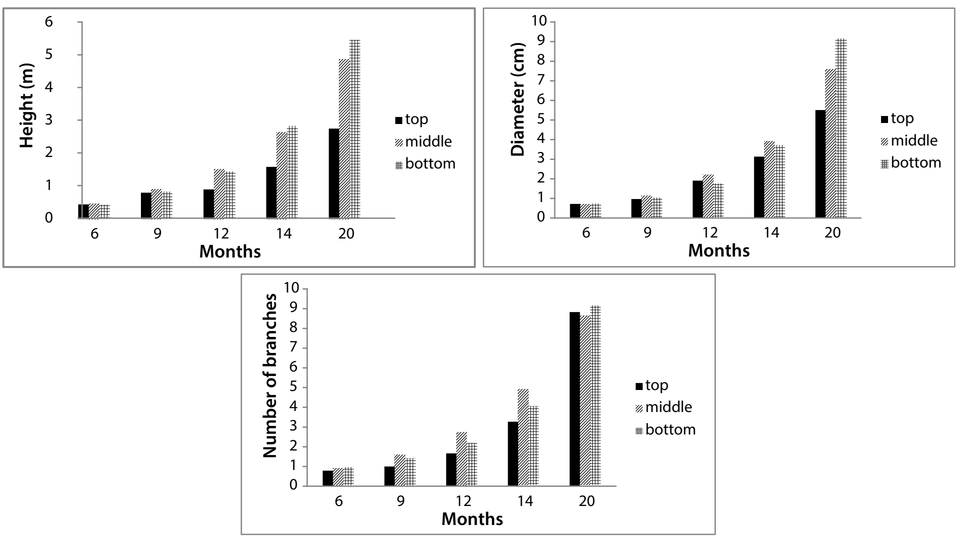

Figure 4. Mean growth performance under three different slope conditions

Table 6. Average soil chemical properties at the *nyamplung* trial plots in Bukit Soeharto Forest

Plot	pH H_2O	C-org (%)	N-Total (%)	C/N	P-Total (ppm)	Ca	Mg	K	Na	KTK	Base Saturation (%)
						(cmol(+)/kg)					
1	4.48	1.46	0.19	7.51	44.37	0.59	0.43	0.20	0.05	14.28	10.01
2	4.49	1.14	0.21	5.47	21.09	0.15	0.31	0.06	0.05	8.08	6.69
3	4.27	1.13	0.20	5.59	39.16	0.15	0.15	0.14	0.05	7.36	7.47
4	4.93	1.13	0.23	4.98	29.35	0.30	0.30	0.11	0.04	42.23	1.59
5	5.14	1.32	0.22	6.06	10.18	0.28	0.28	0.16	0.04	41.40	1.99
Category	very acidic to acidic	low	low to moderate	very low to low	low to high	very low	very low to low	very low to low	very low	low to very high	very low

Height ranged from 0.8–0.9 m at nine months old and 2.8–5.5 m at 20 months old. Slope gradient had an apparent effect on diameter at the end of the observation period (i.e., at 20 months), when diameter ranged between 5.5 and 9.1 cm. Meanwhile, numbers of branches varied between 0.8–1.0 at six months old and 8.6–9.2 at 20 months old.

Soil chemical properties

Soil samples from the trial plots were collected and analysed in the soil laboratory to examine the soils' chemical properties. Table 6 shows that fertility in the study area is low, as indicated by low C-organic content and N-total content. The other indicator supporting low fertility in the area is low soil acidity (pH 4–5).

Landscape restoration and biodiversity

After two years of life as a plantation, the landscape had completely changed from degraded bare hills to a green landscape (see Figure 5). *Nyamplung* trees had already started to flower and fruit. Several bird species and insects, including bees and butterflies, had colonized the two-year-old trees. While flora and fauna surveying and analysis was not covered in this study, it was apparent that establishing bioenergy plantations on degraded land is a promising approach for land restoration and enhancing native biodiversity, while producing renewable energy.

9.3.2 Discussion

Survival rate and environment

Survival rate is an attribute that relates to the adaptation of a species to the planting environment (Birkinshaw et al. 2009). Geographic variation is often the most important

Figure 5. Conditions in the previously burned study site, before and after planting *nyamplung*

Figure 6. Bees, birds and butterflies colonizing *nyamplung* trees

characteristic relating to survival and adaptability (Leksono et al. 2017). The survival rate of *nyamplung* in the trial plots in Bukit Soeharto has been over 90%. This indicates that *nyamplung* from the provenance seed stand in Wonogiri adapted well to the trial site in Bukit Soeharto, despite the two locations having very different characteristics (see Table 1). This survival rate is the same as for *nyamplung* planted as the seed source in Wonogiri at six and 12 months after planting (Windyarini and Hasnah 2014). A study by Hani and Rahman (2016) revealed that four-year-old *nyamplung* tree had survival rates of 97.33% and 68.88%, respectively under agroforestry and monoculture systems on sandy soil in a coastal area of West Java. Meanwhile, among six provenance populations planted on sandy soil in ex-situ conservation plots in Cilacap, Central Java, survival rates at five years old ranged from 44% to 82% (Fiani 2015). Comparing two-year-old *nyamplung* trees on rocky land with thin topsoil in Gunung Kidul, where seeds came from eight different Indonesian islands, survival rates ranged between 77% and 86% (Leksono et al. 2015). Similarly, at 12 months after planting, *nyamplung* had the highest survival rate (52.4%–78.7%) of five species planted on former tin mining land (Cakyayanti and Setiadi 2014).

By the final monitoring visit of this study (24 months after planting), *nyamplung* trees in the trial plots had already started flowering and fruiting. This is another indicator of the good adaptability of *nyamplung* from the provenance seed stand in Wonogiri. The environmental and soil conditions (Tables 1, 3, 4 and 6) in the observation plots were not significantly different to those in Wonogiri, the source of the seeds. One noticeable difference was that of pH. Soil pH in the observation plots tended to be acidic, while in Wonogiri, pH was 7-8 (neutral) (Windyarini and Hasnah 2014). Nevertheless, this pH still meets the prerequisite for growing *nyamplung*, as it is tolerant to a pH range of 4–7.4 (Leksono et al. 2014a). Mean NPK nutrient content (Table 6) was higher in the trial plots than in Wonogiri (N = 0.08%; P = 1.86 ppm; K = 0.12) (Windyarini and Hasnah 2014). Fires on Ultisol soil can cause an increase in nutrients like N, P, K and organic matter, due to the addition of minerals found in ash and charcoal (Sumardi and Widyastuti 2002). However, fires can also destroy on-ground vegetation, with the result that soil structures are damaged, triggering erosion in the rainy season (Choiruddin et al. 2018).

The relatively high survival rates of *nyamplung* are because it can tolerate various soil types including clay, calcareous and rocky soils. *Nyamplung* is classified as a semi-tolerant plant but tends to be more suited to areas with full sunlight exposure (Mangopang and Prasetyawati 2015). In the coastal area of Bukit Soeharto Great Forest Park in East Kalimantan, *nyamplung* dominated at stand and pole stages, with 90.11% and 140.06%, respectively (Mukhlis and Sidayasa 2011). This domination was likely connected to the physical environment, as the coastal forest offers an ideal habitat for *nyamplung*, with a temperature of 25.4°C to 31.7°C, humidity of 75% to 97% and average rainfall of 2,000 mm to 2,500 mm per year. The high survival rate of *nyamplung* in the trial plots indicated high sunlight exposure supported growth. Climatic conditions in the coastal area fall under the same range as those of the *nyamplung* trial plots, although the areas have different soil types and acidity. The coastal area is sandier with high soil acidity, while soil in the trial plots is Ultisol with low soil acidity. As such, it appears possible to expand the planting of *nyamplung* from the Wonogiri provenance seed stand to different types of lands and soils based on its evident survival in these environmental conditions.

Implications of NPK fertilizer and slope gradient

At the beginning of the growth period, 50 g, 100 g and 150 g fertilizer dosage treatments had a significant effect on height, diameter and number of branches. However, the difference in growth performance became insignificant between plots and PMPs with the seedlings' increasing in age. The first year (six to 12 months) after planting is a critical phase for plants in terms of adapting from the nursery environment to the planting site in the field. Plants are more sensitive to external inputs, including fertilizer. Different doses of manure application also result in insignificant differences in height and diameter growth in teak plants (Sudrajat and Bramasto 2009). Fertilizer doses only gave fairly significant effects at the beginning of growth. This could be because the nutrient content in trial plot soils is sufficient to support growth, despite nutrient content being low (Table 6). At the operational scale, fertilizer application must be efficient, as excessive fertilizer may not produce significant results and will increase the operational costs of cropping (Sudrajat and Bramasto 2009). The results of different NPK fertilizer applications in *nyamplung* plants on the previously burned degraded land in Bukit Soeharto suggest that a lower dose (50 g) of fertilizer is sufficient.

Slope positions (top, middle, bottom) provide the same growth performance trends with each fertilizer treatment, up to the age of 20 months. Slope position as a treatment in its own right makes a real difference to growth parameters of height, diameter and number of branches at the beginning of growth (six to 12 months). At this stage, the greatest performance, diameter and number of branches were found at the bottoms of slopes (Figure 4), which may be due to additional nutrients leaching from higher up. At 14–20 months, slope position has no discernible effect, except on diameter. The insignificant differences could be down to nutrient content supporting plant growth until the age of 20 months (Table 5). Slope position also had no significant effect on the height and diameter of *sengon* trees at four months old, on revegetated land at the former Berau coal mine in East Kalimantan (Syauqie et al. 2019).

Flowering and fruiting

Calophyllum inophyllum generally starts flowering seven years after it is first planted (Bustomi et al. 2008). However, with intensive silviculture, *Calophyllum inophyllum* in Wonogiri's provenance seed stand in Central Java began to flower 18 months after planting (Leksono et al. 2016). In the previously burned trial plots in Bukit Soeharto Research and Education Forest, *nyamplung* was observed to start flowering and fruiting at the age of 24 months. This could be influenced by the low phosphorus (P) content in the soil (Table 6). The availability of water and P in the soil is a major limiting factor in the adaptability and growth of *nyamplung* in Wonogiri (Windyarini and Hasnah 2014). The reproductive cycle (flowering and fruiting) is one indicator of adaptation when a species is planted or developed in a particular location. As a comparison, in degraded peat swamps, *Calophyllum soulatri* begins fruiting at three years old (Darwo and Bogidarmanti 2016). The reproduction process is influenced by many factors; the formation of fruit is affected by the amount of synchronization, the maturity of males and female flowers, pollinator effectivity, amount of sunlight, altitude, temperature, rainfall, site conditions and management practices (Nurtjahjaningish and Widyatmoko 2012; Handoko et al. 2013; Putri et al. 2014).

Biodiversity and ecosystem services

There is ongoing concern and lack of agreement about the expansion of feedstock production for biofuels, and associated impacts on biodiversity and ecosystem services (Gasparatos et al. 2011). Depending on the location, previous land use, condition, planning and management, the establishment of biofuel crops may result in positive and/or negative impacts on the environment, including habitats, biodiversity, soil and water conservation (McBride et al. 2011). In this case, the plantation of bioenergy crops in a degraded and previously burned landscape demonstrated positive results on land restoration and habitat quality. However, as the research site is only just over two years old, it is too early to determine the full impacts on biodiversity and habitat quality.

9.4 Conclusions

Bioenergy crops have huge potential for restoring degraded landscapes and supporting climate and development goals in Indonesia. With a huge landmass and variety of climatic conditions, a wide range of biofuel species can be grown in different site conditions. This study demonstrated growth performance of two-year old *nyamplung* trees on an extremely degraded and frequently burned landscape, revealing it as a viable option for restoring degraded landscapes while growing an alternative source of energy. Findings prove that *nyamplung* has high adaptability to different soil types. The research shows that *nyamplung* has potential for being taken from experimental scale to pilots and wider implementation in various parts of Indonesia. Research and development organizations need to engage with small and medium enterprises and community groups to develop projects and business models at appropriate scales and in suitable contexts. We would urge that bioenergy development avoids arable land and forest conservation sites, to avoid food, energy and environmental conflicts.

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