CHAPTER 7

Suitability of bioenergy tree species on degraded peatlands in Central Kalimantan, Indonesia

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Abstract: Vast areas of degraded peatlands in Kalimantan need a sustainable long-term restoration mechanism, ideally one that can address energy security without compromising food production or biodiversity conversation. This research assesses the survivability and growth performance of potential bioenergy crops: *gamal* (*Gliricidia sepium* (Jacq.) Walp.), *kaliandra* (*Calliandra calothyrsus Meissner*), *kemiri sunan* (*Reutealis trisperma* (Blanco) Airy Shaw) and *nyamplung* (*Calophyllum inophyllum* L.), that could be cultivated to produce bioenergy and restore degraded peatlands. Parameters observed were tree height and stem diameter growth as well as plant survival rates. Trials was conducted on a two-hectare demonstration plot on burned degraded peatland in Buntoi Village, Pulang Pisau District, Central Kalimantan Province. Using a split plot design, two treatments were applied to each species, i.e., agroforestry (intercropped with *Ananas comosus* (L.) Merr.) and monoculture plantation. For each species, these treatments were replicated in two separate subplots. Results indicate *nyamplung* being the most adaptable species, followed by *kemiri sunan*, and both species performing better under agroforestry than monoculture treatments. Further study is needed to assess productivity and associated biofuel yields.

Keywords: bioenergy, agroforestry, peatland restoration
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7.1 Introduction

Due to population growth, urbanization and economic development, Indonesia's demand for bioenergy has increased significantly (IEA 2015), with depleting fossil fuel sources unable to meet increasing energy demands into the future (Firdaus et al. 2015). Whilst responding to interests in renewable energy and degraded land restoration, bioenergy can provide a potential alternative to meet growing energy demand. The Government of Indonesia has mandated to increase renewable energy production, including bioenergy, with the aim of renewables making up 23% of the national energy mix by 2025 (GoI 2014). However, expansion of bioenergy production could trigger competition with other land uses, such as food production and biodiversity conservation. To avoid such competition, degraded land has been identified as a potential target for bioenergy production (Nijsen et al. 2012). Central Kalimantan Province has a significant area of degraded land, estimated at approximately 7.2 million hectares (ha) (ICCC 2014). Forest conversion for other land uses, such as agriculture and open pit mining, is a key factor driving land degradation (Suwarno 2016). Frequent forest fire occurrence, particularly in recent years, has driven an escalation in degraded land, including degraded peatlands (Page et al. 2002). Fires have affected agricultural land managed by local farmers, causing productivity to fall, resulting in most burned land, including peatland, being abandoned due to its reduced fertility (Carlson et al. 2013).

Central Kalimantan is also facing energy deficits, with 42% of households in the province having no access to electricity (GGGI 2015). Consumption of biomass in traditional cooking practices is relatively high (IRENA 2017). To increase community access to energy, the central government, through the Ministry of Energy and Mineral Resources (ESDM), in collaboration with district and provincial governments, has initiated a bioenergy programme called Bioenergi Lestari. The programme involves planting bioenergy crops on approximately 62,500 ha of abandoned land, including degraded land in Pulang Pisau and Katingan districts, with the expectation of increasing bioenergy production (Rony 2015). However, very few studies provide useful information on bioenergy crops suitable for growing on degraded lands in Central Kalimantan. To fill this knowledge gap, this research project aimed to identify the most adaptable bioenergy crops suitable for degraded lands, and gauge their performance in agroforestry and monoculture systems.

As large areas, particularly peatlands, affected by deforestation and forest degradation need a viable long-term solution for restoration linked to energy security and producing renewable energy, the performance of bioenergy crops in restoring peatlands needed to be tested. This research aimed to assess the performance of potential bioenergy crops, and their potential for restoring burned and degraded peatlands without compromising food security.

7.2 Materials and methods

Buntoi Village, located between 02°48’59.4” S and 114°10’47.3” E in the district of Pulang Pisau in Central Kalimantan, Indonesia (Figure 1) was selected as the study site. Buntoi, with a total land area of 16,261.595 ha, is dominated by forest and agricultural land (Figure 2). Its soils are predominantly peat and alluvial. The village has a humid tropical climate with temperatures ranging from 26.5 to 27.5°C. The Ministry of Energy and Mineral Resources and the local government has chosen Buntoi Village as one of a number of locations under the Bioenergi Lestari project.

Buntoi has a total population of 2,729, most of whom depend on farming and rubber and *sengon* (*Albizia chinensis*) plantations (Buntoi Village Government 2017). In late 2015, Buntoi Village was badly affected by forest and peat fires, which destroyed large areas of farmers’ productive land, including approximately 461 ha of rubber plantations. The burned land has since been abandoned, and farmers are now looking for alternative land uses to meet their livelihood needs.

Trials were conducted between March 2016 and February 2017 on two hectares of degraded peatland. Having a total of 16 subplots, a split plot design was applied to test the performance of four potential biofuel species under two different treatments: monoculture and agroforestry with a system involving intercropping with pineapple. The two-hectare total area of the plots limited the number of possible replications to only two.

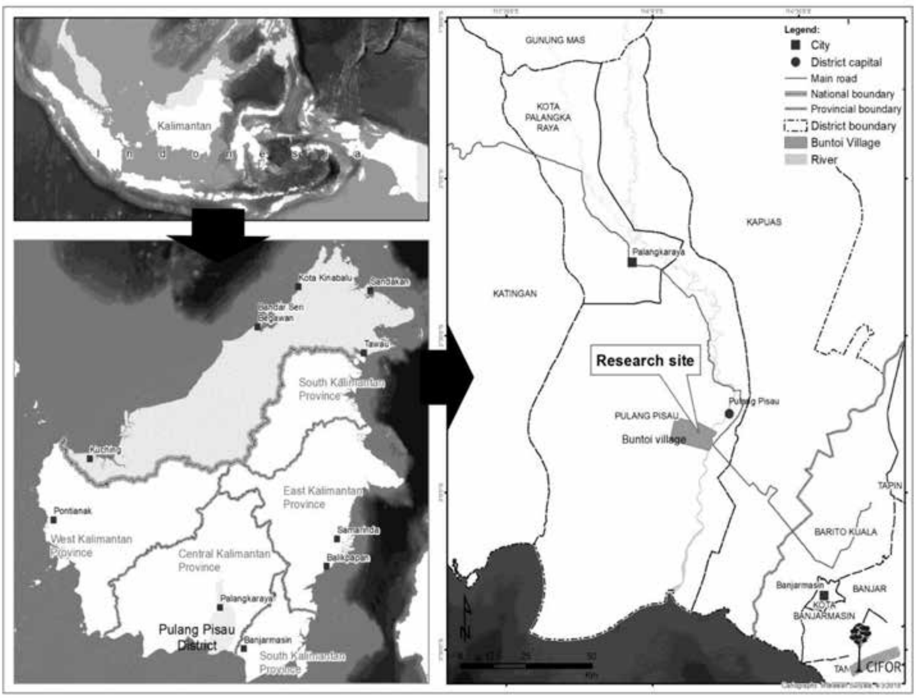

Figure 1. Location of Buntoi Village in Central Kalimantan Province, Indonesia

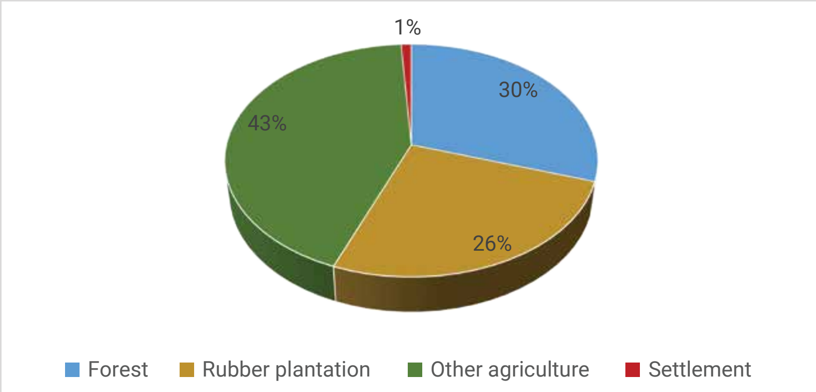

Figure 2. Land uses in Buntoi Village

Four species: *Gamal* (*Gliricidia sepium*), *kaliandra* (*Calliandra calothyrsus*), *kemiri sunan* (*Reutealis trisperma*) and *nyamplung* (*Calophyllum inophyllum*) were selected to test their capacity to adapt to extreme environmental conditions in degraded peatlands. Previous studies had suggested that *nyamplung* is adaptable to waterlogged areas (Leksono et al. 2014), *kaliandra* is tolerant to acidic soils of pH 4–5 (Palmer et al. 1995), *kemiri sunan* is adaptable to marginal land (Perry et al. 2013) and *gamal* is tolerant to acidic soils (Bhattacharya 2003) (Table 1.).

Parameters observed in our study included tree height (cm) and stem diameter (mm) measured from 10 cm above ground level. Survival rates were also observed by counting the total number of saplings surviving in each plot. Data were recorded on a monthly basis using the above parameters. As the research site was a fire-prone area, to ensure the safety of the trial plots we used a six-metre firebreak to separate the plots from natural vegetation and four-metre firebreaks to separate them from rubber trees and a road. We also used six-metre breaks between the different treatment plots. In terms of plant spacing, the different species were spaced as follows: *kaliandra* and *gamal* (2 m x 1 m), *kemiri sunan* and *nyamplung* (8 m x 8 m) and pineapple (*Ananas comosus*) (1 m x 1 m).

Table 1. Adaptability of selected bioenergy crops

No.	Species	Type of biomass	Adaptation capability	References
1	*Kaliandra*	wood	Acidic soil (pH 4.9–5.3) and drought	Leksono et al. 2014; Vijay et al. 2016
2	*Nyamplung*	seed	Saline soil and waterlogged areas	Abram at al. 2017; Gaveau et al. 2016
3	*Malapari* (*Pongamia pinnata*)	seed	Saline soil and waterlogged areas	Arun et al. 2017; Mainoo and Ulzen-Appiah 1996
4	*Kemiri sunan*	seed	Areas with slope gradient of 15%–40%	Perry et al. 2013; Zi et al. 2012
5	*Gamal*	wood	Acidic soil (pH < 5.5)	Ong et al. 2011; Orwa et al. 2009

Peatland depth profiles and pH values were also measured from four sample points in the trial plots by measuring their distance from a river, i.e., two samples taken 50 m from the river and two samples taken 200 m from the river. In addition to descriptive statistics, the results of non-parametric Kruskal-Wallis tests and post-hoc results of Wilcoxon rank-sum tests in R software (version 3.4.4) were used to analyse the data.

7.3 Results and discussion

Peatland depth and pH values in the study plots ranged from 56 cm to 87 cm and from 2.88 to 3.19, respectively (Table 2). These showed that with a medium acidity level, peatland depth was relatively thicker in proximity to the river. The survival rates of energy crops shown in Figure 3 suggest that with survival rates of 88% and 48% respectively, *nyamplung* and *kemiri sunan* are adaptable to degraded peatlands. *Kaliandra* and *gamal*, however, were unable to survive in our trial plots. We may conclude, therefore, that only *nyamplung* and *kemiri sunan* are viable options for planting on burned degraded peatlands.

Table 2. Peat depth profile and pH values in the trial plots

Sample no.	Distance from river (m)	pH value	Peat depth (cm)
1	50	2.88	85.00
2	50	2.95	87.00
3	200	2.81	77.00
4	200	3.19	56.00

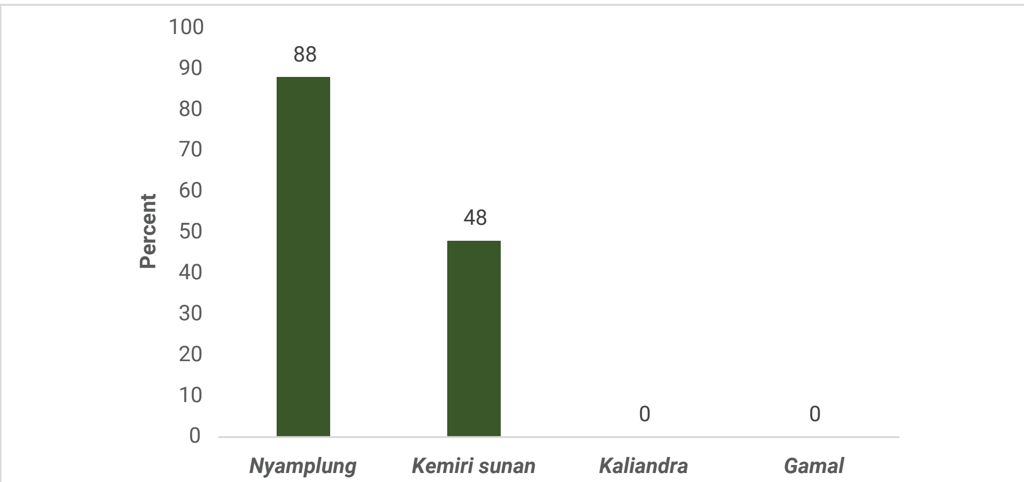

Figure 3. Survival rates of the four selected bioenergy species

Figures 4 and 5 show the growth rates in study plots for *nyamplung* and *kemiri sunan*; the two trialled species adaptable to degraded land. Growth rates for *nyamplung* were steady in all conditions except agroforestry plot B, where the growth rate was comparatively high for months five and six, after which it became steady. Growth rates for *kemiri sunan* remained steady under all conditions except monoculture plot B, where the growth rate for the first and last month was comparatively high. Higher growth rates for these months may have been due to external input and weather condition factors, i.e., fertilizer application and rainfall/sunlight, respectively. The figures also indicate that both species experienced better growth rates with intercropping than under monocultures. Nevertheless, further investigation is necessary to determine which external factors affect growth. Our data also illustrates stem diameter growth increasing steadily for both *nyamplung* and *kemiri sunan* under intercropping and monoculture systems (Figures 6 and 7).

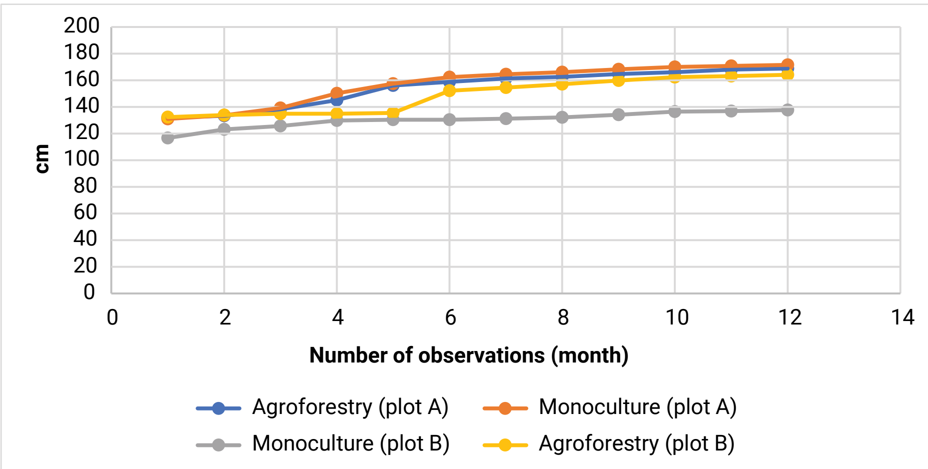

Figure 4. Tree height growth for *nyamplung*

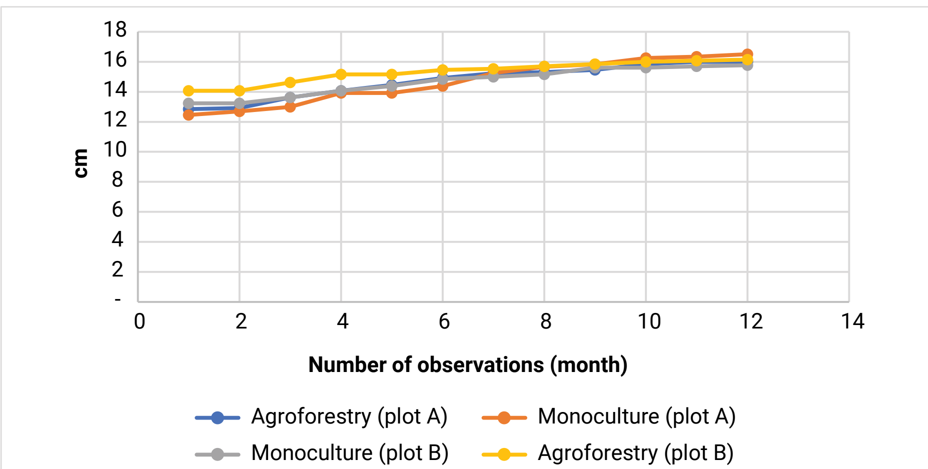

Figure 5. Tree height growth for *kemiri sunan*

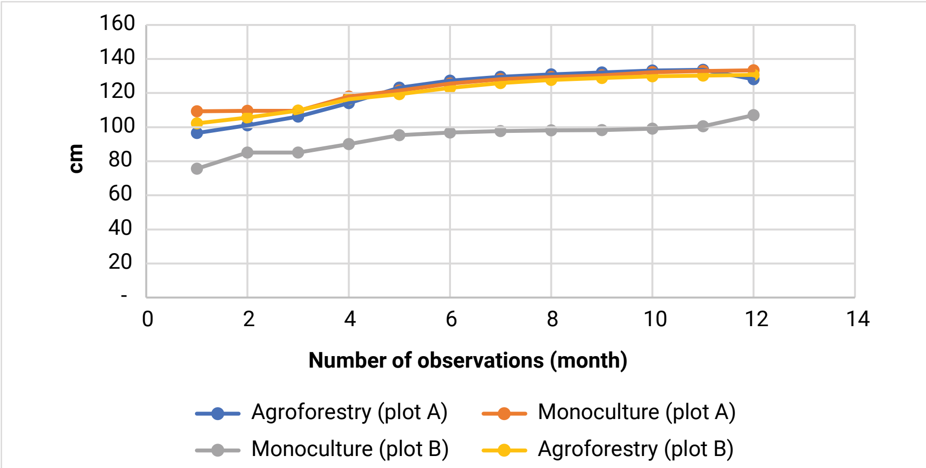

Figure 6. Stem diameter growth for *nyamplung*

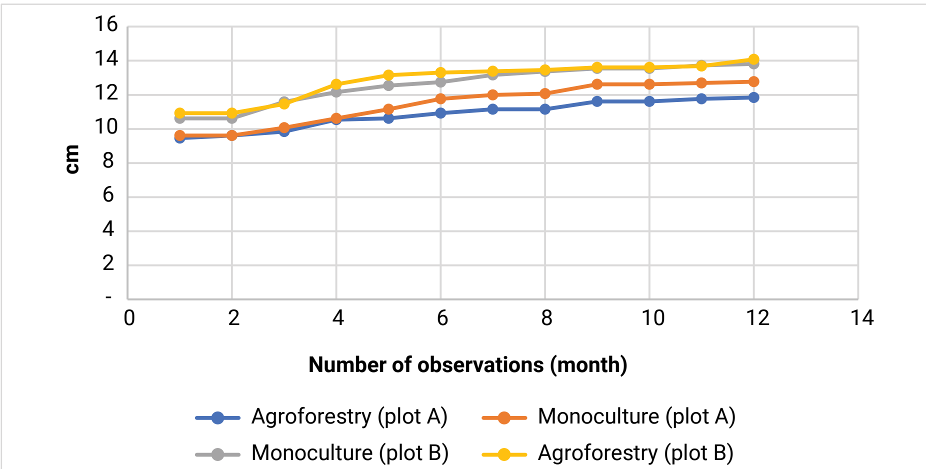

Figure 7. Stem diameter growth for *kemiri sunan*

Our Wilcoxon rank-sum tests further showed *nyamplung* performing better than *kemiri sunan* for both tree height and stem diameter growth (Figures 8 and 9). Both species performed better for tree height growth under agroforestry than monoculture treatments (Figure 10). However, only *nyamplung* performed well for stem diameter growth under agroforestry conditions (Figure 11).

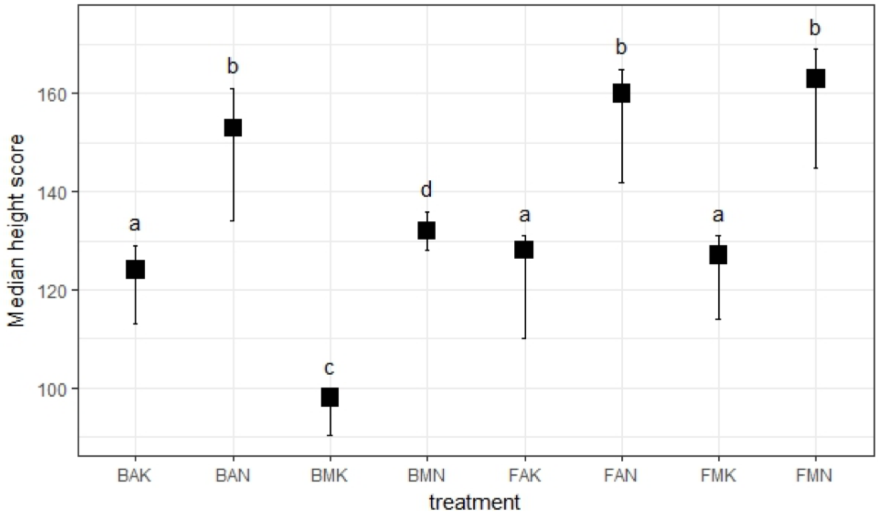

Figure 8. Results of Wilcoxon rank-sum tests on tree height for *nyamplung* and *kemiri sunan*

Notes: BAK = *kemiri sunan* agroforestry plot B; BAN = *nyamplung* agroforestry plot B; BMK = *kemiri sunan* monoculture plot B; BMN = *nyamplung* monoculture plot B; FAK = *kemiri sunan* agroforestry plot A; FAN = *nyamplung* agroforestry plot A; FMK = *kemiri sunan* monoculture plot A; and FMN = *nyamplung* monoculture plot A). Letters a, b, c and d show different tree height performance levels.

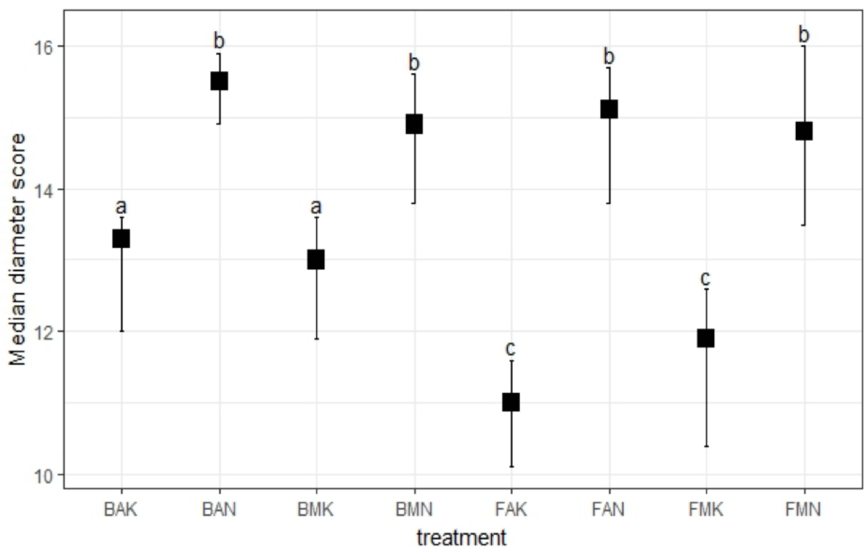

Figure 9. Results of Wilcoxon rank-sum tests on stem diameter for *nyamplung* and *kemiri sunan*

Notes: BAK = *kemiri sunan* agroforestry plot B; BAN = *nyamplung* agroforestry plot B; BMK = *kemiri sunan* monoculture plot B; BMN = *nyamplung* monoculture plot B; FAK = *kemiri sunan* agroforestry plot A; FAN = *nyamplung* agroforestry plot A; FMK = *kemiri sunan* monoculture plot A; and FMN = *nyamplung* monoculture plot A). Letters a, b and c show different stem diameter performance levels.

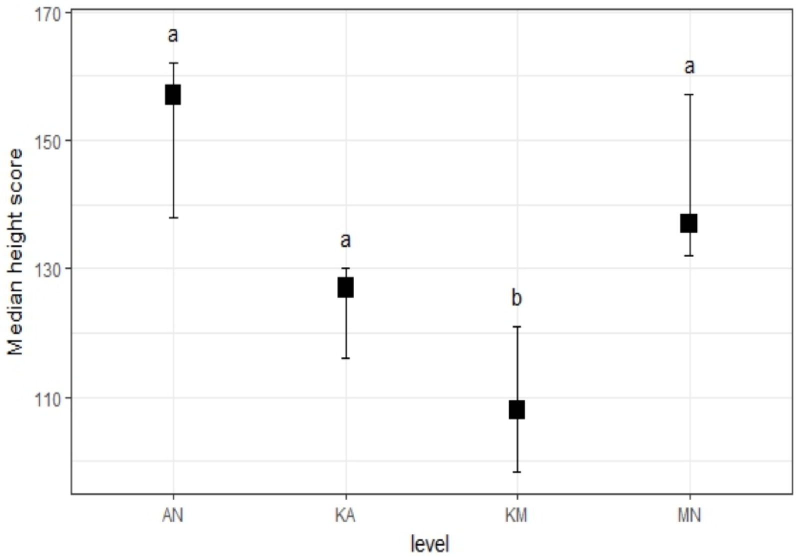

Figure 10. Results of Wilcoxon rank-sum tests on tree height under agroforestry and monoculture treatments for *nyamplung* and *kemiri sunan*

Notes: AN = *nyamplung* agroforestry; KA = *kemiri sunan* agroforestry; KM = *kemiri sunan* monoculture; and MN = *nyamplung* monoculture). Letters a and b show different tree height performance levels.

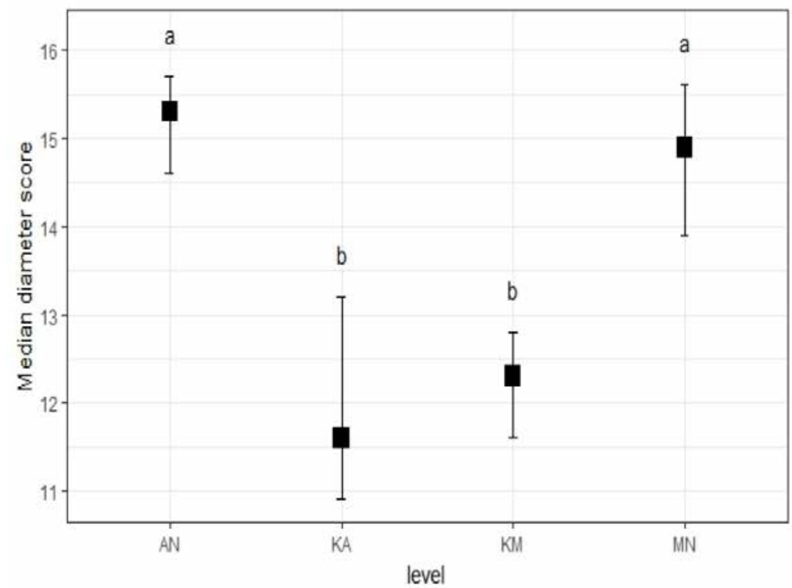

Figure 11. Results of Wilcoxon rank-sum tests on stem diameter under agroforestry and monoculture treatments for *nyamplung* and *kemiri sunan*

Notes: AN = *nyamplung* agroforestry; KA = *kemiri sunan* agroforestry; KM = *kemiri sunan* monoculture; and MN = *nyamplung* monoculture). Letters a and b show different stem diameter performance levels.

Our research shows *nyamplung* to be the species most adaptable to burned and degraded peatlands in Central Kalimantan, followed by *kemiri sunan*. Both species performed more favourably under agroforestry than monoculture treatments. This appears to be a win-win solution, as growing biofuel under agroforestry systems can be a better land-use strategy, considering the potential to enhance farm production and incomes, protect biodiversity and support sustainable development (Dagar et al. 2014). If the target is to motivate local farmers to use their degraded land for biofuel production, it is essential to consider that tree growing by farmers is often associated with multiple objectives influenced by livelihood necessities and local cultures (Rahman et al. 2008). Current literature emphasizes farmers' capacity to adopt tree planting being dependent on production technology, adequate physical infrastructure and developed markets for tree products (Shuren and Snelder 2008). Improved understanding of these circumstances is crucial for policy improvements to succeed in making tree planting feasible, acceptable and ultimately profitable for local people and related stakeholders (Franzel and Scherr 2002).

Planting millions of square kilometres of biofuel plantations could sequestrate huge amounts of carbon annually while also providing adequate energy stock (Mooney 2018). Supportive policies could further assist biofuel production on degraded land to avoid compromising agricultural production and to avert negative environmental consequences.

7.4 Conclusion

This study demonstrates that with survival rates of 88% and 48%, respectively, *nyamplung* and *kemiri sunan* were the most suitable of the four trialled bioenergy producing species for cultivation on degraded peatlands in Central Kalimantan. Neither *gamal* nor *kaliandra* appear to be viable options as none of the planted saplings survived. Growth performance indicators show that *nyamplung* grew better in agroforestry than monoculture treatment plots, in terms of both tree height and stem diameter. Similarly, *kemiri sunan* performed better in terms of tree height growth in agroforestry plots. This awareness of *nyamplung* and *kemiri sunan*'s capacity to survive on degraded peatlands and their improved performance under agroforestry systems can help promote the benefits of agroforestry and enhance farmers' livelihoods in addition to supporting sustainable development. Nevertheless, further studies are necessary on the production performance of both species to supplement the data.

Further studies are also needed to trial different species on different degraded peatlands. These should include more accurate extended measurement variables, such as soil nutrients, peat water table and peat depth. Selecting tree species with multiple benefits in terms of livelihoods, local culture familiarity and strong market value, may be beneficial for improving farmers' motivation to utilize degraded lands for biofuel production.

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