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Restoring Land and Growing Renewable Energy: Opportunities, Challenges, and the Future Steps

(Restorasi Tanah dan Pembuatan Energi Terbarukan: Peluang,Tantangan, dan Langkah ke Depan)

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ABSTRACT

Primary energy demand in Indonesia has rapidly increased, i.e., 43.33% between 2005 and 2016, while domestic energy supply failed to fulfill these needs leading to the reliance on the energy import. Meanwhile, a vast area of degraded land in Indonesia also created an opportunity for biofuel production, fulfilling energy demand, as well as restoring the land with environmental and socio-economic benefits. This paper provides an overview of identified potential and challenges associated with biofuel production from degraded land in Indonesia. Our preliminary findings highlighted that some biofuel species in Indonesia are suitable to grow in degraded land and potentially restore the land that may not be suitable for current agricultural production and/or reforestation. The initial finding also shows that culturally familiar species and stable markets are favorable terms of biofuel-species selection for the landowners. Supportive agricultural-extension services such as knowledge and technology for honey production can provide an added value in this concept, in addition to social (e.g., strengthening social solidarity and employment opportunities) and environmental (e.g., carbon storage, soil moisture, erosion control, and biodiversity) benefits. Meanwhile, to create this overall initiative to be successful, a supportive measure from the policymakers is needed. Further research on the capacity of biofuel species to restore degraded lands in different biophysical profiles. Analysis of biofuel production feedstocks and potential co-benefits viable business models, and the stable market is necessary to maximize benefit from biofuel productionand to restore the degraded lands in Indonesia.

Keywords: biofuel production, renewable energy, restoring

ABSTRAK

Permintaan energi primer di Indonesia telah meningkat pesat, yaitu 43,33% antara tahun 2005 dan 2016, sementara pasokan energi dalam negeri gagal memenuhi kebutuhan ini dan menyebabkan ketergantungan pada impor energi. Sementara itu, luas lahan terdegradasi di Indonesia juga menciptakan peluang untuk produksi biofuel, memenuhi permintaan energi, serta memulihkan lahan dengan manfaat lingkungan dan sosial ekonomi. Makalah ini memberikan ikhtisar potensi yang diidentifikasi dan tantangan yang terkait dengan produksi biofuel dari lahan kritis di Indonesia. Temuan awal kami menyoroti bahwa beberapa spesies biofuel di Indonesia cocok untuk tumbuh di lahan terdegradasi dan berpotensi memulihkan lahan yang mungkin tidak cocok untuk produksi pertanian pada saat ini dan / atau reboisasi. Temuan awal juga menunjukkan bahwa spesies yang dikenal secara budaya dan pasar yang stabil adalah istilah yang baik untuk pemilihan spesies biofuel bagi pemilik tanah. Layanan penyuluhan pertanian yang mendukung seperti pengetahuan dan teknologi untuk produksi madu dapat memberikan nilai tambah dalam konsep ini, selain manfaat sosial (mis. Memperkuat solidaritas sosial dan kesempatan kerja) dan lingkungan (mis. penyimpanan karbon, kelembapan tanah, pengendalian erosi, dan keanekaragaman hayati). Sementara itu, untuk membuat inisiatif keseluruhan ini menjadi sukses, diperlukan langkah dukungan dari pembuat kebijakan. Penelitian lebih lanjut tentang kapasitas spesies biofuel untuk memulihkan lahan terdegradasi dalam berbagai profil biofisik sangat dibutuhkan. Analisis bahan baku produksi biofuel dan potensi manfaat tambahan, model bisnis yang layak, dan pasar yang stabil diperlukan untuk memaksimalkan manfaat dari produksi biofuel dan untuk memulihkan lahan terdegradasi di Indonesia.

Kata kunci: energi terbarukan, produk *biofuel,* restorasi

INTRODUCTION

Indonesian energy demand has significantly increased primarily due to the population growth, urbanization, and economic development (IEA 2015). At the same time, sources of fossil fuel havedepleted and are unable to fulfill the increasing

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energy demands of the future (Firdaus *et al.* 2015). Whilst responding to interests in renewable energy and degraded land restoration, bioenergy can also provide a potential alternative to meet the growing energy demands. The Indonesian government has mandated for increasing renewable energy production, including bioenergy, with the aim of meeting 23% of total energy use by 2025 (GOI 2014). However, such expansion of bioenergy production could triggercompetitions with the other land uses, such as food production and biodiversity conservation. To avoid such competition, degraded land has been identified as a potential target area for bioenergy production (Nijsen *et al.* 2012). Central Kalimantan Province is the province with the most significant amounts of degraded land in Indonesia, estimated at approximately 7.2 million hectares (ha) (ICCC 2014). Forest conversion to other types of land use, e.g., agriculture and open mining, is one of the key driving factors of land degradation (Suwarno 2016). The frequent occurrence of forest fires, particularly in recent years, has driven an escalation in degraded land, including peatland (Page *et al.* 2002). The occurrence of the fire has also affected agricultural land managed by local farmers and declined its productivity. Most of the burned land, including peatland, has been abandoned due to its declining fertility (Carlson *et al.* 2013). Central Kalimantan Province is also facing energy deficits with significant numbers of households (42%) in the province having no access to electricity (GGGI 2015). Consumption of traditional biomass for cooking purposes is also 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, initiated a bioenergy program called Bioenergi Lestari. The program will plant bioenergy crops on approximately 62,500 ha of abandoned land, including degraded land in two districts, i.e., Pulang Pisau and Katingan, 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, particularly in Central Kalimantan. To fill this scientific-knowledge gap, this research project aimed to identify the most adaptive bioenergy crop(s) for degraded lands, and their production performances while intercropping.

Large areas of deforestation and forest degradation, particularly on the peatlands, need a viable and long-term solution to restore linking to energy security to obtain renewable energy. Therefore, the performance of bioenergy crops to restore peatlands need to be tested. This research aimed to assess the performance of potential bioenergy crops, mainly to restore burned and degraded peatlands, without compromising food security.

MATERIAL AND METHODS

This study was conducted in Buntoi Village (located between 02°48’59.4 S and 114°10 47.3 E) in the district of Pulang Pisau, Central Kalimantan, Indonesia (Figure 1). Buntoi, with a total land area of 16,261.595 ha, is dominated by forest and

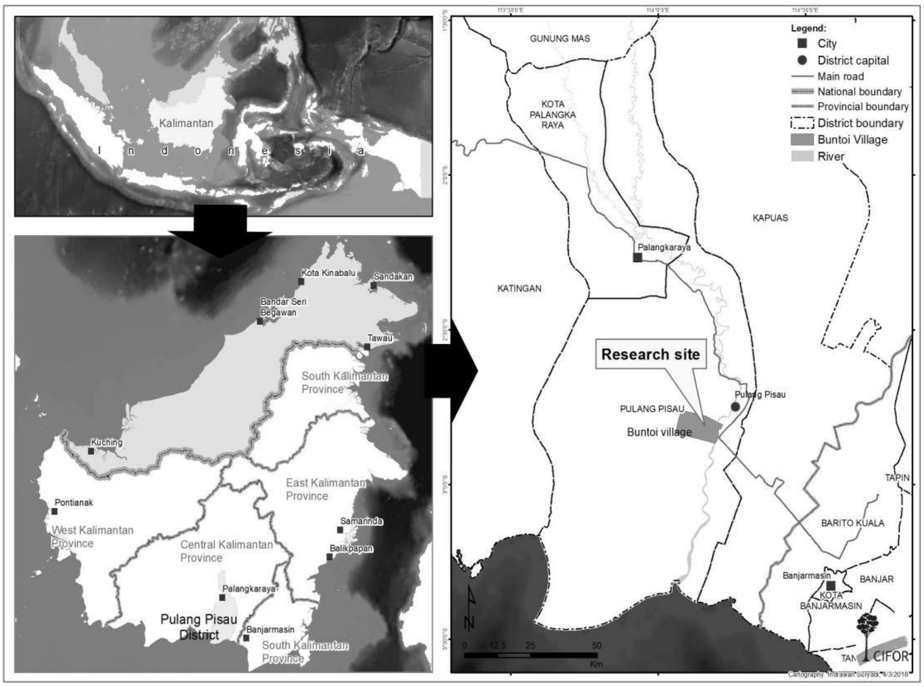

Figure 1 Location of Buntoi Village in Central Kalimantan, Indonesia.

agricultural land (Figure 2). Soil domination is mainly peat and alluvial. Buntoi has a tropical and humid climate with a temperature ranging from 26.5 to 27.5°C. The village was selected as one of the locations for bioenergy crop plantation initiated by the Ministry of Energy and Mineral Resources (ESDM) and the local government under the Bioenergi Lestari Project.

The total population of Buntoi is 2,729; this population is mainly dependent on agriculture (Buntoi Village Administration 2017), rubber, and Sengon (*Albizia chinensis*) plantations. In late 2015, Buntoi village was affected by forest and peatland fires, which destroyed large areas of farmers' productive land, including approximately 461 ha of rubber plantation. The burned land has since been abandoned, and farmers are now looking for alternative land uses to meet their livelihood needs.

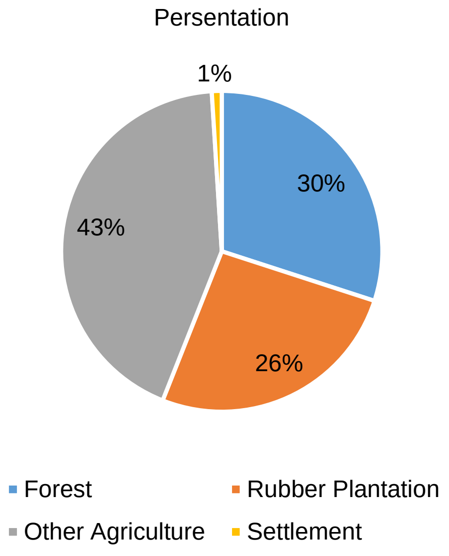

Figure 2 Land uses in Buntoi village.

The experiment was carried out between March 2016 and February 2017 on two hectares of degradedpeatland. Having a total of 16 subplots, a split-plot design was applied to test the performance of four biofuel crop species with two different treatments, i.e., under monoculture and agroforestry conditions; with agroforestry conditions involving intercropping with pineapple. Each species under each treatment was replicated twice on two separate plots, i.e. A and B (Figure 3). As the total experimental plot area was two hectares, this limited the number of replications possible to two.

Four species, i.e., Gamal (*Gliricidia sepium*), kaliandra (*Calliandra calothyrsus*), kemiri sunan (*Reutealis trisperma*), and nyamplung (*Calophyllum inophyllum*), were selected to test their adaptive capabilities in extreme environmental conditions, i.e., degraded peatlands. Previous studies suggested that nyamplung is adaptive to waterlogged areas (Leksono *et al.* 2014), kaliandra is tolerant to acidic soil (pH 4–5) (Palmer *et al.* 1994), and kemiri sunan is adaptive to marginal land. Gamal is also tolerant to acidic soil (Bhattacharya 2003) (Table 1).

Observed parameters in our study included plant height (in cm) and plant diameter (in mm) measured from 10 cm above the ground. Survival rate also observed by counting the total number of survived saplings in each plot. Data were recorded every month using the above parameters. Since the research site is a fire-prone area, for the safety of the experimental plot, we used a six-meter firebreak from natural vegetation and four-meter firebreaks from rubber trees and the road. We also used a six-meter break between different treatments (Figure 3). In terms of plant spacing, species was spaced as follows: kaliandra and Gamal (2 m x 1 m), kemiri sunan and nyamplung (8m x 8 m), and pineapple (*Ananas comosus*) (1mx 1m).

The peatland depth profile and pH value were also measured from four sample locations of our study plots by measuring their distances from the river, i.e.,

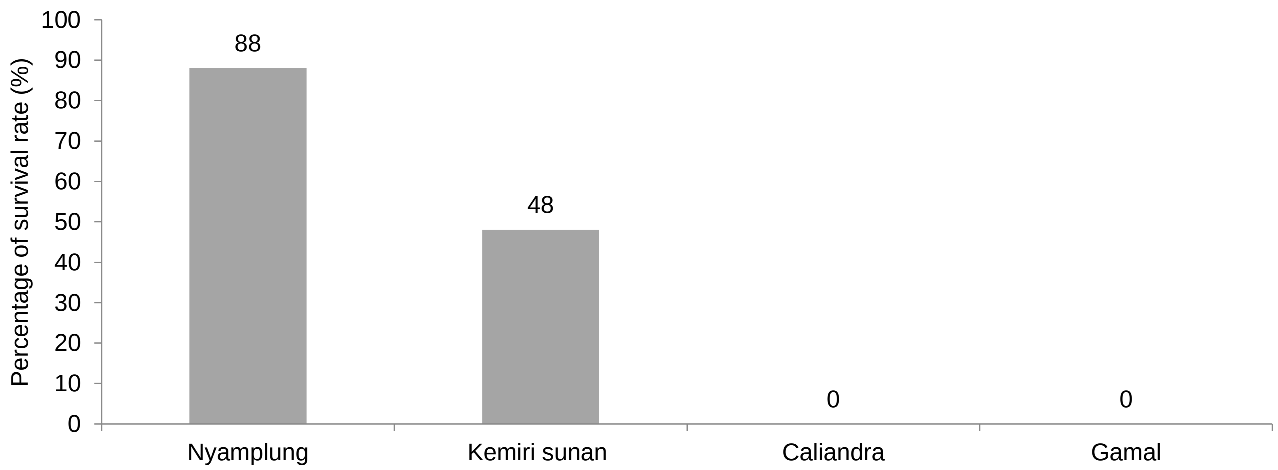

Figure 3 The survival rate of the four selected bioenergy species.

two samples 50 m from the river and two samples 200 m from the river. Besides descriptive statistics, a nonparametric test, i.e., Kruskal-Wallis and post-hoc test results of a Wilcox on rank-sum test in R software (version 3.4.4), were used to analyze the data.

RESULTS AND DISCUSSION

Peatland depth and pH in the study plot ranged from 56 cm to 87 cm and 2.88 to 3.19, respectively (Table 2), which showed that with the medium acidity level, peatland depth was relatively higher when in proximity to the river. The survival rates of bioenergy crops are shown in Figure 4. Results indicated that nyamplung and kemiri sunan were adaptable to degraded peatland, with respective survival rates of 88% and 48%. However, kaliandra and Gamal did not survive in our experimental plot. Therefore, it can be concluded that only nyamplung and kemiri sunan are useful for planting in burned and degraded peatlands.

Figures 5 and 6 show the growth rate on degraded peatland of nyamplung and kemiri sunan, the two adaptable trialed species. For nyamplung, the growth rate was steady in all conditions except agroforestry (plot B) conditions where the growth rate from month 5 to 6 was comparatively high and after that became steady again. For kemiri sunan, under all conditions, the growth rate remained steady, except monoculture (plot B) where growth rates during the first and last month were comparatively high. Higher growth rates in a specific month for both species, as mentioned above, might be due to external inputs, i.e., fertilizer application, and weather conditions, e.g., rainfall or sunlight. The figures also indicated that with intercropping, both species showed better growth than under monoculture. However, further investigation is needed to examine the external factors that affected growth. Our data also illustrated that the circular stem growth of nyamplung and kemiri sunan steadily increased both under intercropping and monoculture systems (Figure 7 and 8).

Our Wilcoxon rank-sum test further showed that nyamplung performed better for both tree height and circular stem growth compared to kemiri sunan (Figure 9 and 10). We were looking at the two different treatments (i.e., agroforestry and monoculture). Both species performed better for tree-height growth under agroforestry (Figure 11). However, only nyamplung performed well for circular stem growth under agroforestry (Figure 12).

Our research shows that nyamplung is the most adaptable species, followed by kemiri sunan when

Table 1 Review of adaptability of selected bioenergy crops

Species	Type of biomass	Adaptation capability	Reference
Kaliandra	wood	Acidic soil (pH 4.9–5.3) and drought	[20,21]
Nyamplung	seed	Saline soil and waterlogged areas	[17-19]
Malapari (Pongamiapinnata)	seed	Saline soil and waterlogged areas	[28,29]
Kemiri sunan	seed	Slope areas (15–40%)	[30,31]
Gamal	wood	Acidic soil (pH < 5.5)	[23,24]

Table 2 Peatland depth profile and pH value of the study plots

Sample no	Distance from the river (in cm)	pH value	Peatland depth (in 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

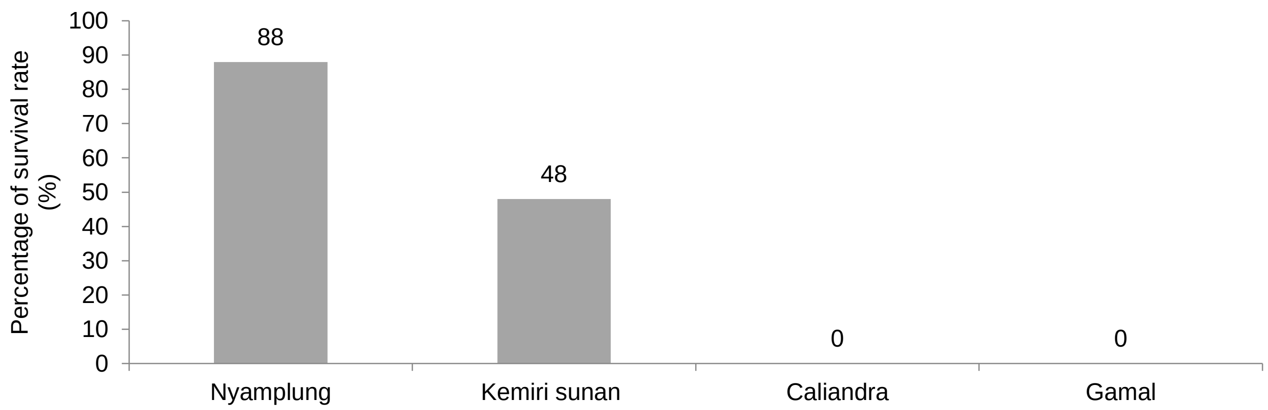

Figure 4 The survival rate of the four selected bioenergy species.

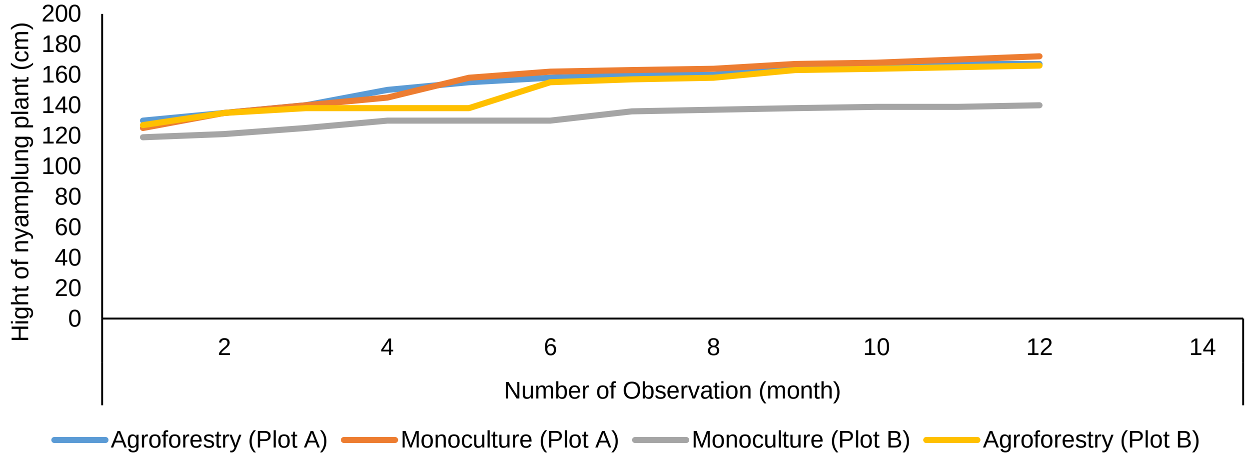

Figure 5 Growth of nyamplung plant in several plots of agroforestry and monoculture during 12 month of observation.

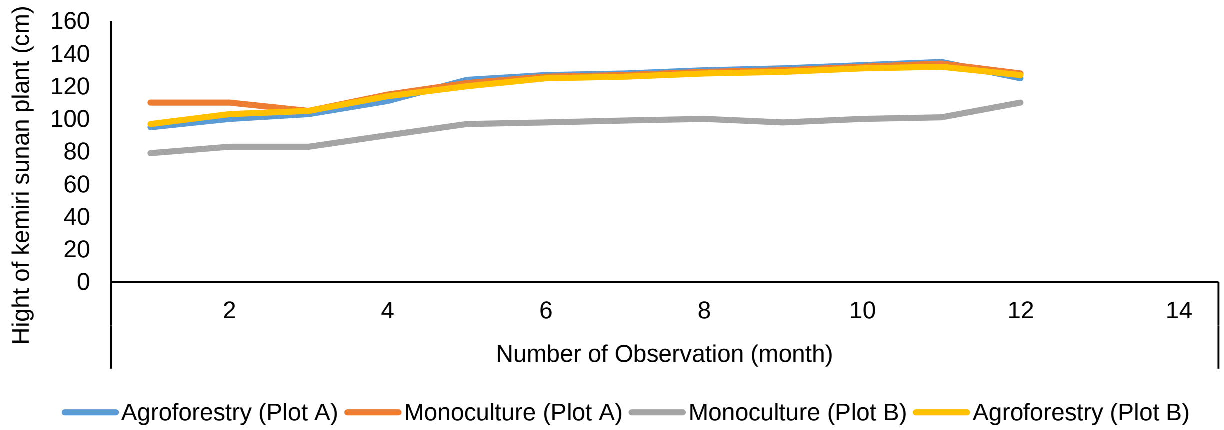

Figure 6 Growth of kemiri sunan plant in several plots of agroforestry and monoculture during 12 month of observation.

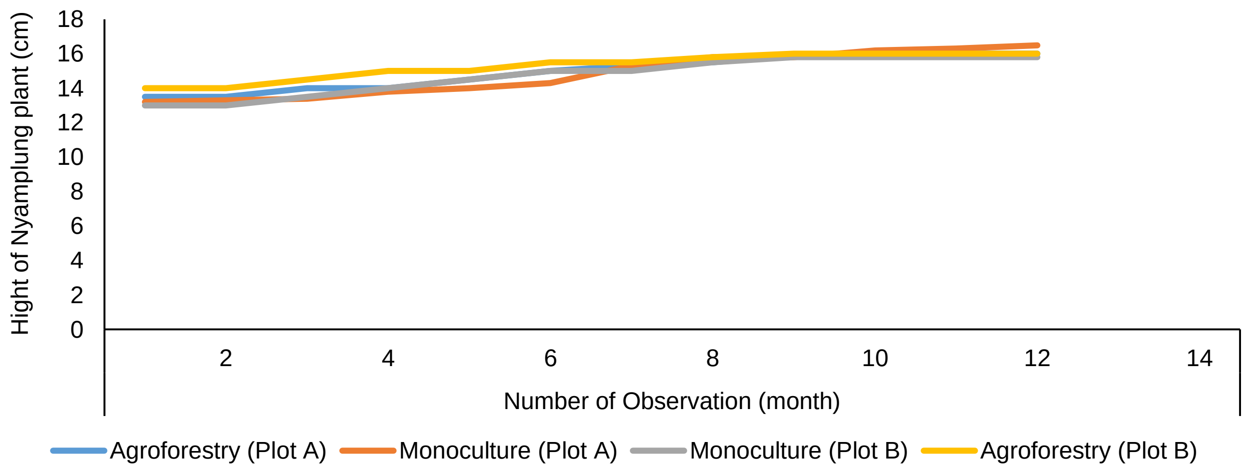

Figure 7 Circular-stem growth of nyamplung in several plots of Agroforestry and monoculture during 12 month observation.

grown on burned and degraded peatland in Central Kalimantan. However, both species performed very well under agroforestry treatment compared to the monoculture. This is a win-win solution, as growing biofuel using an agroforestry system can be a better land-use strategy, considering its potential to enhance farm production and income, protect biodiversity, and support sustainable development (Dagar *et al.* 2014). If the target is also 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 influencedby livelihood necessities and local cultures (Rahman *et al.* 2008). Current literature emphasizes

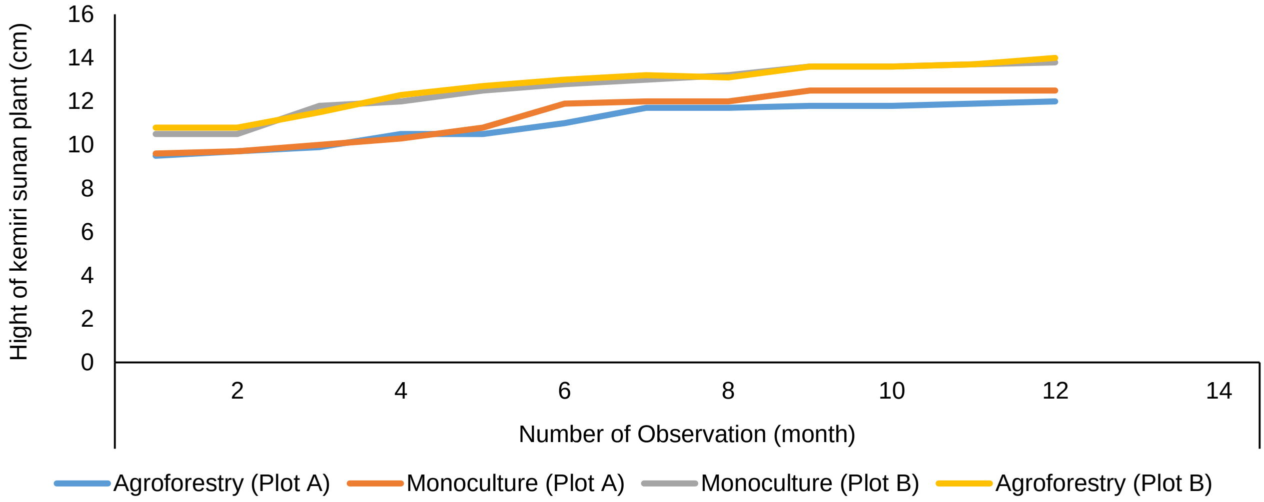

Figure 8 Circular-stem growth of kemiri sunan in several plots of Agroforestry and monoculture during 12 month observation.

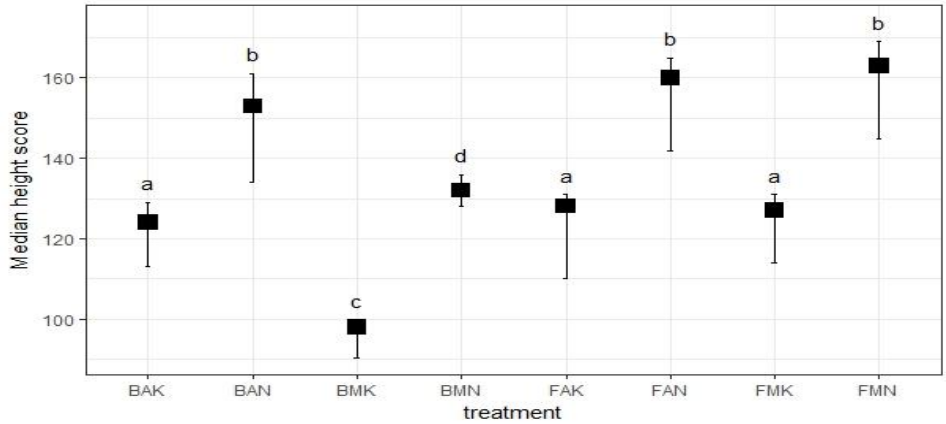

Figure 9 Results of Wilcoxon rank-sum test on tree heights for nyamplung and kemiri sunan (BAK = agroforestry kemiri sunan plot B; BAN = agroforestry nyamplung plot B; BMK = monoculture kemiri sunan plot B; BMN = monoculture nyamplung plot B; FAK = agroforestry kemiri sunan plot A; FAN = agroforestry nyamplung plot A; FMK = monoculture kemiri sunan plot A; FMN = monoculture nyamplung plot A). The letters a, b, c, and d on the figure show different performance levels of height.

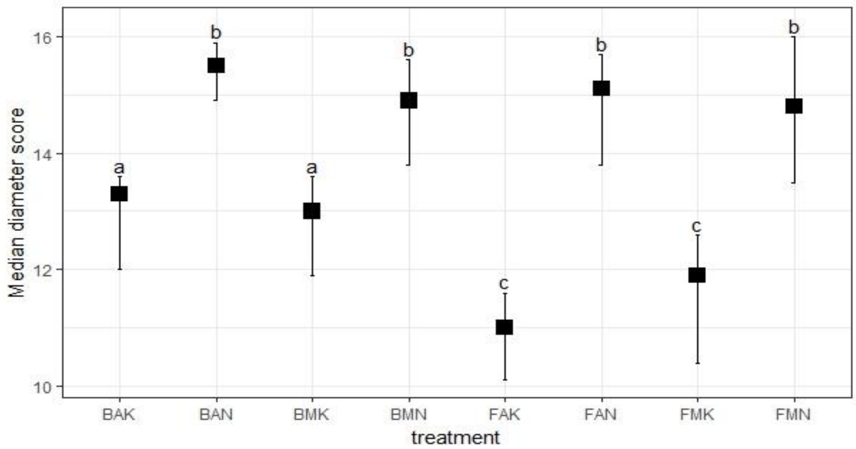

Figure 10 Results of Wilcoxon rank-sum test on tree diameters for nyamplung and kemiri sunan (BAK = agroforestry kemiri sunan plot B; BAN = agroforestry nyamplung plot B; BMK = monoculture kemiri sunan plot B; BMN = monoculture nyamplung plot B; FAK = agroforestry kemiri sunan plot A; FAN = agroforestry nyamplung plot A; FMK = monoculture kemiri sunan plot A; FMN = monoculture nyamplung plot A). The letters a, b, and c on the figure show different performance levels of diameter.

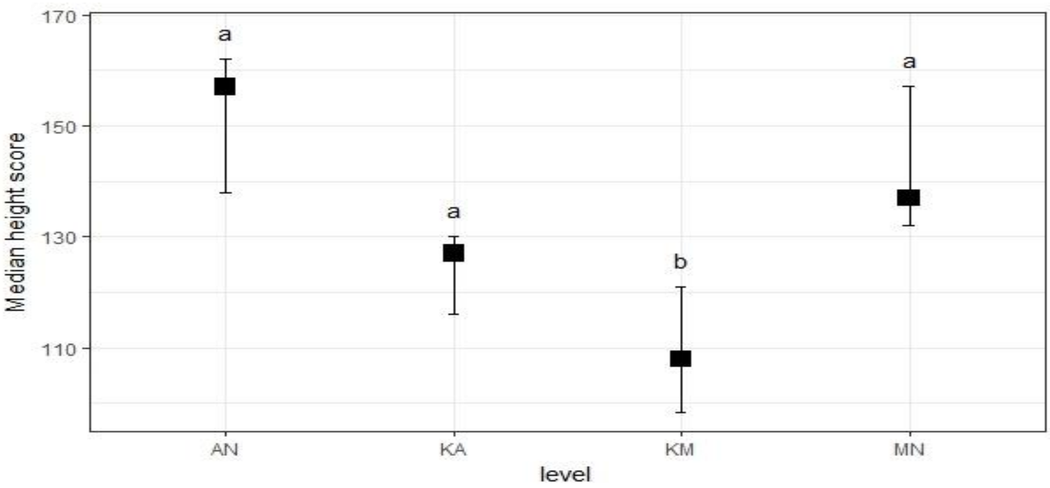

Figure 11 Results of the Wilcoxon rank-sum test on tree heights under two different treatments, i.e., agroforestry and monoculture, for nyamplung and kemiri sunan (AN - agroforestry nyamplung; KA - agroforestry kemiri sunan; KM - monoculture kemiri sunan; MN - monoculture nyamplung). The letters a and b on the figure show different performance levels of height.

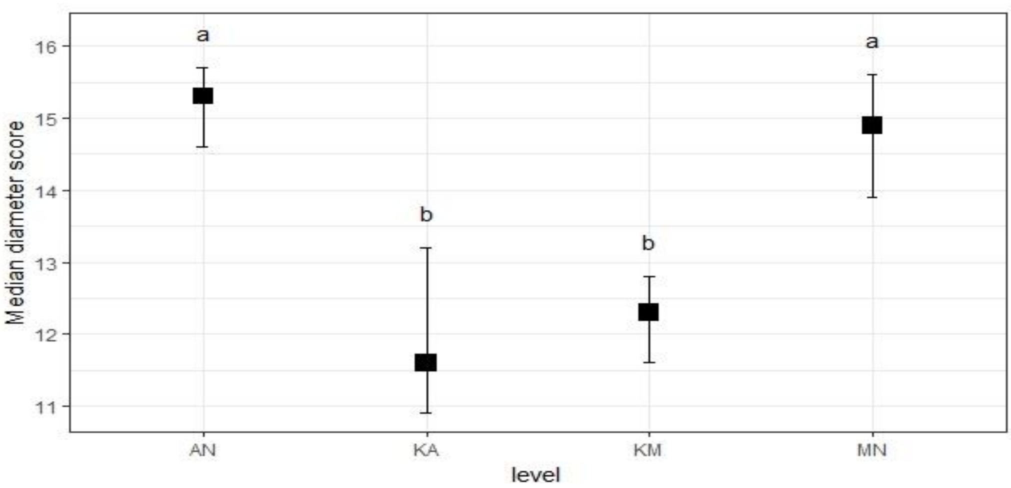

Figure 12 Results of the Wilcoxon rank-sum test on tree diameters under two different treatments, i.e., agroforestry and monoculture, for nyamplung and kemiri sunan (AN - agroforestry nyamplung; KA - agroforestry kemiri sunan; KM - monoculture kemiri sunan; MN - monoculture nyamplung). The letters a and b on the figure show different performance levels of diameter.

farmers' capacity to adopt tree planting is also dependent on production technology, adequate physical infrastructure, and developed markets for tree products (Schuren & 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 stockholders (Franzel & Scherr 2002).

Planting millions of square miles of biofuel could store between 1.2 and 6.3 billion tons of carbon/year; enough to make a huge dent in global greenhouse gas emissions (Baral & Lee 2016), while also providing sufficient energy stock (Mooney 2018). However, there is a risk that doing so could lead to forest clearance, compete with agricultural production and put additional pressure on biodiversity (Baral & Lee 2016). As a solution, producing biofuel on degraded land can avoid compromising agricultural production and the related negative environmental consequences.

CONCLUSION

This study demonstrated that among four trial species, nyamplung is the most adaptive (88%) bioenergy species to grow on degraded peatland in Central Kalimantan, followed by kemiri sunan(48%); while gamal and kaliandra did not survive. Growth performance indicators showed that nyamplung grew better in agroforestry sub-plots compared to monoculture sub-plots both in terms of height and circularstem growth; likewise, kemiri sunan performed better in terms of height growth in agroforestry sub-plots. This awareness of nyamplung and kemiri sunan's survivability in degraded peatland, as well as their improved performances using agroforestry, can promote the benefits of agroforestry and enhance farmers' livelihoods, as well as supporting sustainable development. However, further study on the production performance of both species is needed to complete the data.

Further studies are also needed for different trial species on different peat and degraded land areas, including more accurate extended measurement variables, e.g., 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 to improve farmers' motivation to utilize degraded land for bio fuel production.

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