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Article

Assessment of Suitability of Tree Species for Bioenergy Production on Burned and Degraded Peatlands in Central Kalimantan, Indonesia

Siti Maimunah [1], Syed Ajijur Rahman [2,*], Yusuf B. Samsudin [2], Yustina Artati [2], Trifosa Iin Simamora [2], Sarah Andini [2], Soo Min Lee [3] and Himlal Baral [2]

1. Faculty of Agriculture and Forestry, University Muhammadiyah Palangkaraya (UMP), Central Kalimantan 73111, Indonesia; sitimararil@gmail.com
2. Center for International Forestry Research (CIFOR), Bogor (Barat) 16115, Indonesia; Y.samsudin@cgiar.org (Y.B.S.); Y.artati@cgiar.org (Y.A.); T.simamora@cgiar.org (T.I.S.); S.andini@cgiar.org (S.A.); H.baral@cgiar.org (H.B.)
3. National Institute of Forest Science, Seoul 02455, Korea; lesoomin@gmail.com

* Correspondence: s.rahman@cgiar.org; Tel.: +62-251-8622-622

Received: 6 September 2018; Accepted: 29 September 2018; Published: 7 October 2018

Abstract: Large areas of deforested and degraded land, particularly degraded peatlands, need a viable long-term solution for restoration, ideally one that ensures energy security without compromising food security or biodiversity conversation. To address a knowledge gap on the most adaptive bioenergy crop(s) for degraded lands, this research project assessed the survival and growth performance of potential bioenergy crops to restore burned and degraded peatlands. Our methodology compared the bioenergy species with the potential to survive in extreme environments, i.e., gamal [*Gliricidia sepium* (Jacq.) Walp.], kaliandra (*Calliandra calothyrsus* Meissner), kemiri sunan [*Reutealis trisperma* (Blanco) Airy Shaw], and nyamplung (*Calophyllum inophyllum* L.). Observed parameters are plant survival rates, tree height, and circular stem growth. The experiment was conducted between March 2016 to February 2017 in a two-hectare demonstration plot on burned and degraded peatland in Buntoi village, Pulang Pisau, Central Kalimantan province. Using a split plot design, two treatments were given to each species, i.e., monoculture plantation and agroforestry (intercropped with *Ananas comosus* (L.) Merr.); with each treatment, the species were replicated on two separate plots. Results indicate that nyamplung is the most adoptable species followed by kemiri sunan, however both species performed very well under agroforestry treatment when compared with monoculture. Further study is needed to assess the productivity and associate biofuel yield.

Keywords: land restoration; nyamplung; kemiri sunan; agroforestry; policy

1. Introduction

Indonesian energy demand has significantly increased, primarily due to population growth, urbanization, and economic development [1]. At the same time, sources of fossil fuel have depleted and they are unable to fulfill the increasing energy demands of the future [2]. Whilst responding to interests in renewable energy and degraded land restoration, bioenergy can provide a potential alternative to meet growing energy demands. The Indonesian government has mandated for increases in renewable energy production, including bioenergy from plant sources (e.g., *Calophyllum inophyllum* L., *Elaeis guineensis* Jack.), with the aim of it meeting 23% of total energy use by 2025 [3]. However, such expansion of plantations for energy production could trigger competition with other land uses, such as food production and biodiversity conservation[1]. To avoid such competition, and to diversify bioenergy production, degraded and underutilized land has been identified as a potential target area for bioenergy production [4–7].

Central Kalimantan province has one of the largest amounts of degraded land in Indonesia, estimated at approximately 7.2 million hectares (ha) [8]. Forest conversion to other types of land use, e.g., agriculture and open mining, is one of the key driving factors land degradation [9–11]. The frequent occurrence of forest fires, particularly in recent years, has driven an escalation in degraded land, including peatland [11,12]. The occurrence of fire has also affected agricultural land that is managed by local farmers and declined its productivity. Most of the burned land, including peatland, has been abandoned due to its declining fertility [13]. The Central Kalimantan province is also facing energy deficits, with large number of households (42%) in the province having no access to electricity [14]. Consumption of traditional biomass for cooking purposes is also relatively high [15]. 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 aims to establish bioenergy plantations on approximately 62,500 ha of degraded and abandoned lands in two districts, i.e., Pulang Pisau and Katingan, with the expectation of increasing bioenergy production [16]. However, the progress so far is slow due to very few studies providing useful information on bioenergy crops that are suitable for growing on degraded lands, particularly in Central Kalimantan. To fill this scientific knowledge gap, this research project aimed to identify the most promising bioenergy crop(s) for degraded lands.

2. Materials and Methods

This study was conducted in Buntoi village (located between 102°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 agricultural land (Figure 2). The 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. It has two distinct seasons, dry (April–October) and rainy (November–March). 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 2729; this population is mainly dependent on rubber plantation and other subsistence agriculture [17]. In late 2015, Buntoi village was affected by forest and peatland fires that destroyed large areas of farmers' productive land, including approximately 461 ha of rubber plantation. The burned land has since been abandoned, and the farmers are now looking for alternative land uses to meet their livelihood needs.

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[1] As an example, oil palm has been the main source of bioenergy in Indonesia, however, expansion of oil palm production has raised concerns about compromising food production and destroying forests and consequent biodiversity [18–20].

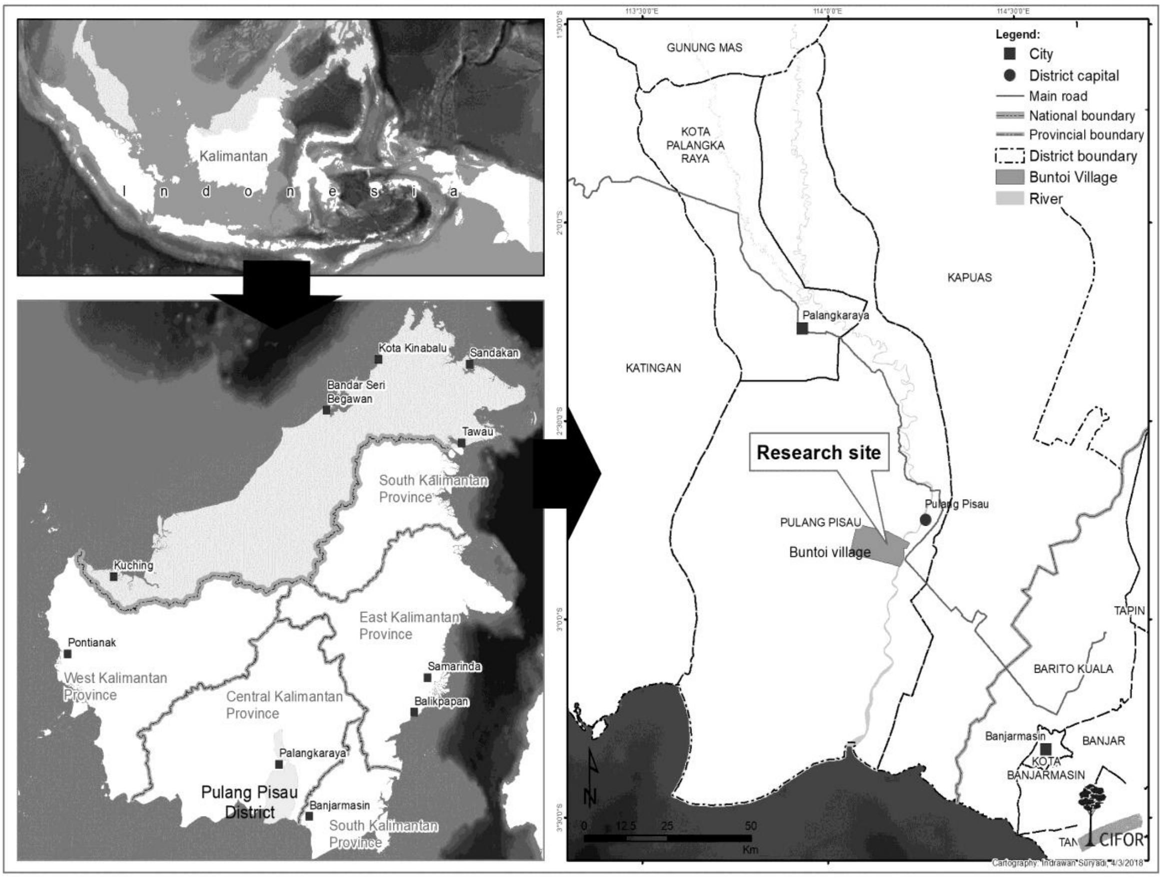

Figure 1. Location of study site (Buntoi village) in Pulang Pisau discticet, Central Kalimantan, Indonesia.

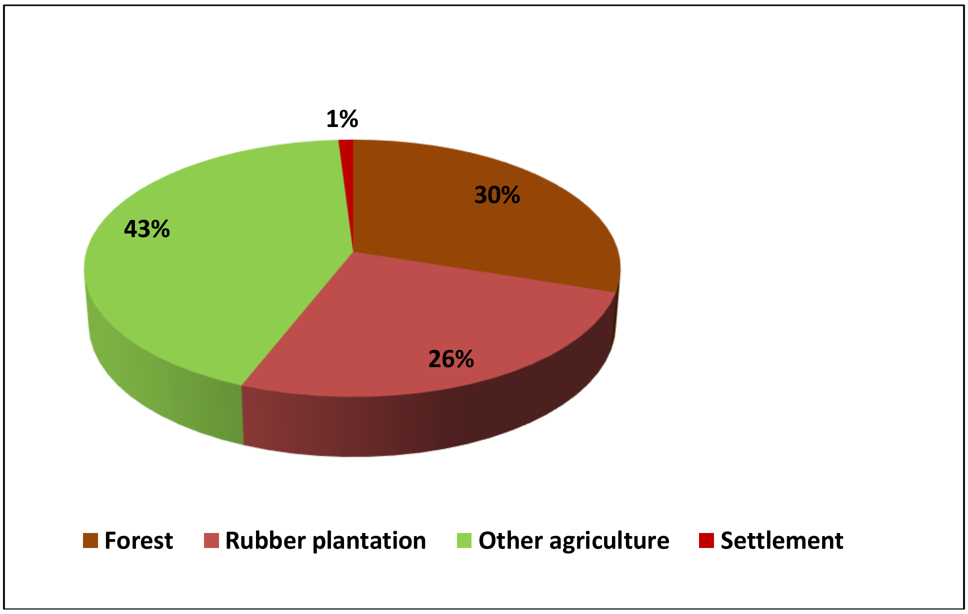

Figure 2. Land uses in Buntoi village [16].

The experiment was carried out between March 2016 and February 2017 on two hectares of degraded peatland. Having a total of 16 sub plots, 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[2] (Figure 3). As the total experimental plot area was two hectares, this limited the number of possible replications to two.

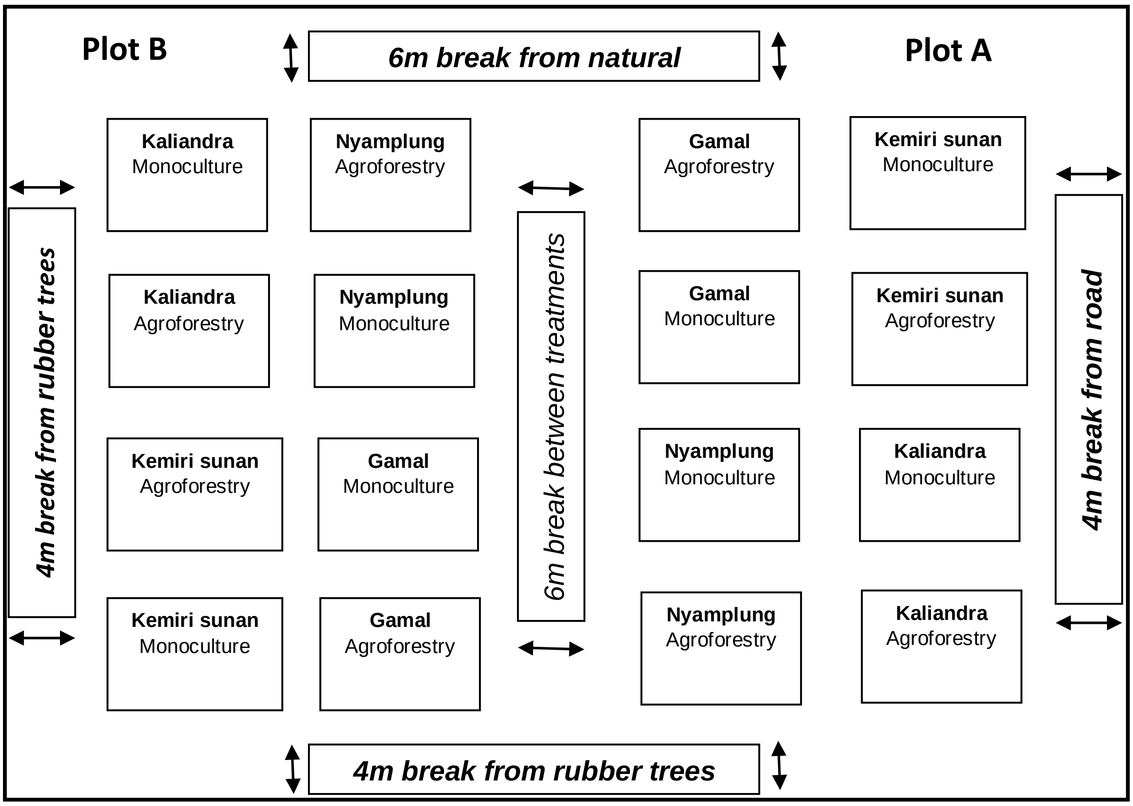

Figure 3. Split plot design for the treatment of four biofuel species in Buntoi research site in Pulang Pisau, Central Kalimantan.

Four species, i.e., gamal [*Gliricidia sepium* (Jacq.) Walp.], kaliandra (*Calliandra calothyrsus* Meissner), kemiri sunan [*Reutealis trisperma* (Blanco) Airy Shaw], and nyamplung (*Calophyllum inophyllum* L.), were selected to test their adaptive capability in extreme environmental conditions, i.e., degraded peatlands[3]. Gamal and kaliandra are well known for biomass production, and kemiri sunan and nyamplung are promising for oil seed production. Previous studies suggested that nyamplung is adaptive to waterlogged areas [21–23], kaliandra is tolerant to acidic soil (PH 4–5) [24,25], and kemiri sunan is adaptive to marginal land [26]. Gamal is also tolerant to acidic soil [27,28] (Table 1).

2 For a similar split plot design method, please see [29–31].

3 Gamal and kaliandra are native species to Central America, while kemiri sunan is known native to the Philippines, and nyamplung to Indonesia [32]. These species require mean annual temperatures 18 to 33 °C with rainfall ranging 60 to 5000 mm, to grow (see Table A1 in Appendix A). The tested species were naturally distributed, and cultivated in Indonesia [32,33]. However, for these tested species, we did not find any literature that can explain commercial scale cultivation in the peatlands. Gamal and kaliandra are utilized to produce energy from its woody biomass [33,34]. Meanwhile, nyamplung and kemiri sunan are utilized for its seeds to be converted to biofuel [35,36].

Table 1. Review of adaptability of selected bioenergy crops to different type of soils.

No	Species	Type of Biomass	Adaptation Capability	Reference
1	Kaliandra	wood	Acidic soil (pH 4.9–5.3) and drought	[24,25]
2	Nyamplung	seed	Saline soil and waterlogged areas	[21–23]
3	Malapari [*Pongamia pinnata* (L.) Pierre]	seed	Saline soil and waterlogged areas	[37,38]
4	Kemiri sunan	seed	Marginal land, slope areas (15–40%)	[26,39,40]
5	Gamal	wood	Acidic soil (pH < 5.5)	[27,28]

Observed parameters in our study included plant height (in cm) and circular stem growth (in mm), measured from 10 cm above the ground. Survival rate was also observed by counting the total number of survived saplings in each plot. Data was recorded every month using above parameters.

As 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 were spaced as follows: kaliandra and gamal (2 m × 1 m), kemiri sunan and nyamplung (8 m × 8 m), and pineapple (*Ananas comosus*) (1 m × 1 m). Fertilizer, i.e., NPK using slow release method, was used in all of the plots.

The peatland depth profile and pH value were also measured from four sample locations of our study plots by measuring their distance from the river, i.e., two samples 50 m from 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 wilcoxon rank sum test in R software (version 3.4.4), were used to analyze the data.

3. 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, showing that with the medium acidity level peatland depth is relatively higher when in proximity to the river.

Table 2. Peatland depth profile and pH value of the study plots in Buntoi research site in Pulang Pisau, Central Kalimantan.

Sample No	Distance from the River (in m)	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

The survival rate of the bioenergy crops is shown in Figure 4. Results indicate that nyamplung and kemiri sunan are adaptable to degraded peatland, with respective survival rates of 88% and 48%. However, kaliandra and gamal did not survive in our experimental plot. Therefore, nyamplung and kemiri sunan are useful for planting in burned and degraded peatlands.

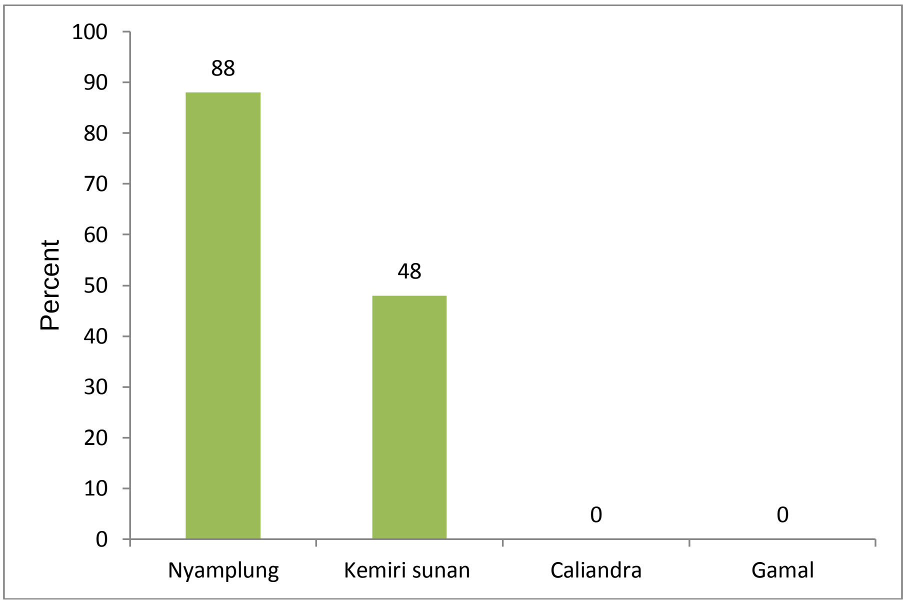

Figure 4. Survival rate of the four selected bioenergy species in Buntoi research site in Pulang Pisau, Central Kalimantan.

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 is steady in all conditions, except agroforestry (plot B) conditions where the growth rate from month 5 to 6 is comparatively high, and after that becomes steady again. For kemiri sunan, under all conditions, the growth rate remains steady, except monoculture (plot B) where growth rate during the first and last month is 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 indicate that with intercropping, both species see 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 (Figures 7 and 8).

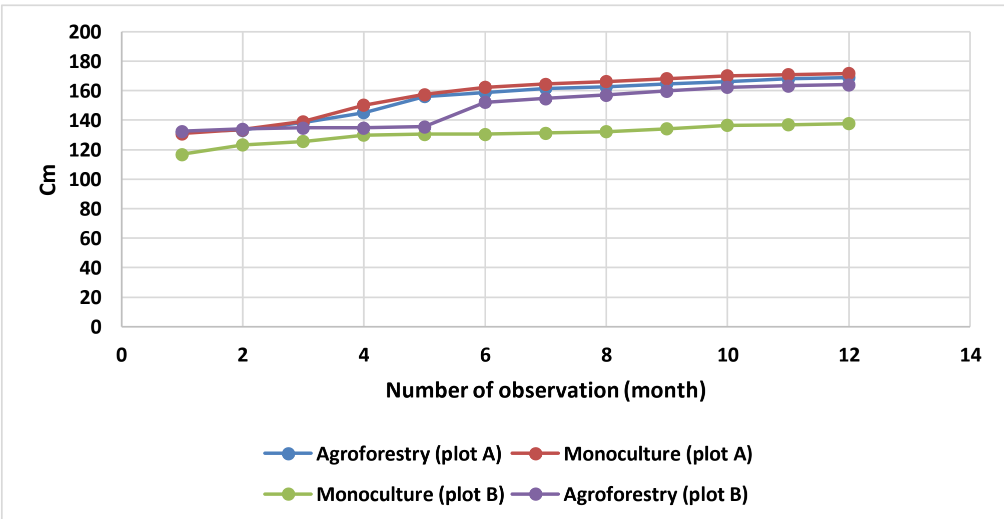

Figure 5. Height growth of nyamplung in monoculture vs. agroforestry plots in Buntoi research site in Central Kalimantan.

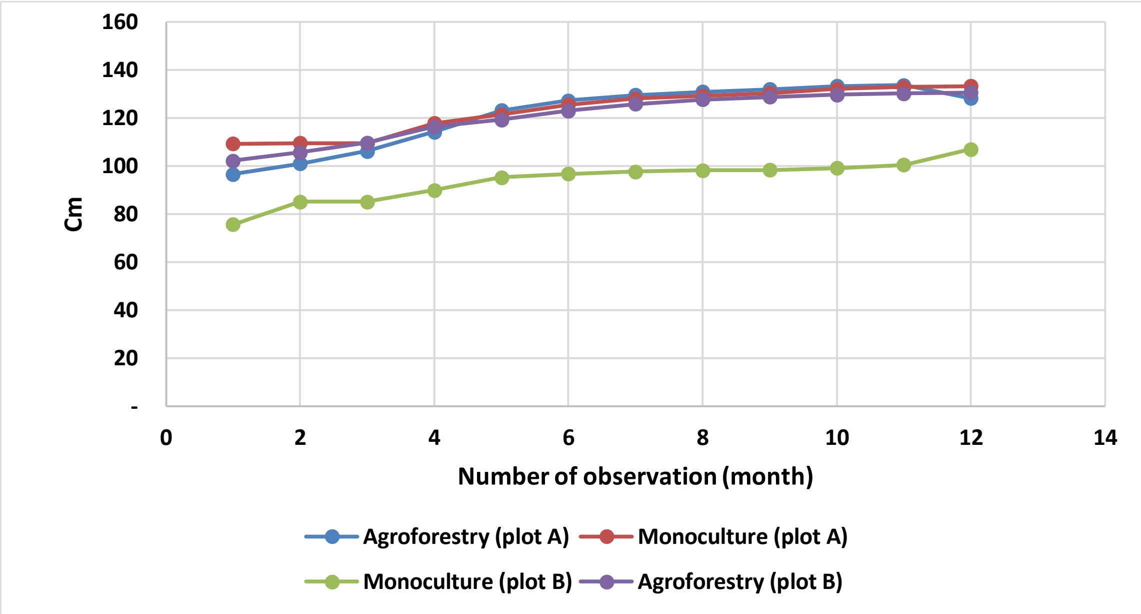

Figure 6. Height growth of kemiri sunan in monoculture vs. agroforestry plots in Buntoi reseaech site in Central Kalimantan.

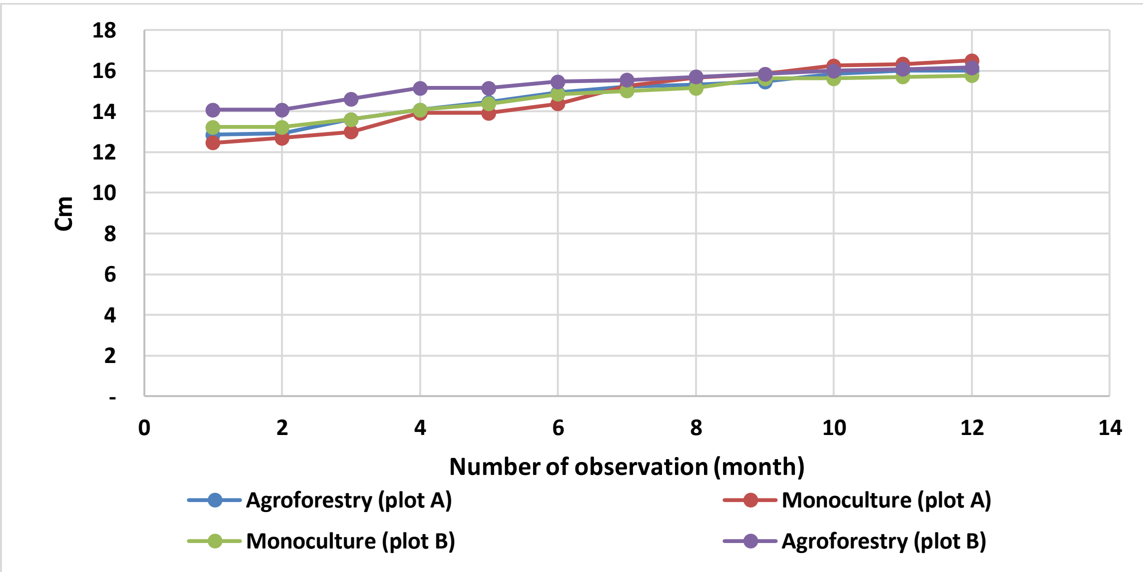

Figure 7. Circular stem growth of nyamplung in monoculture vs. agroforestry plots in Buntoi reseaech site in Central Kalimantan.

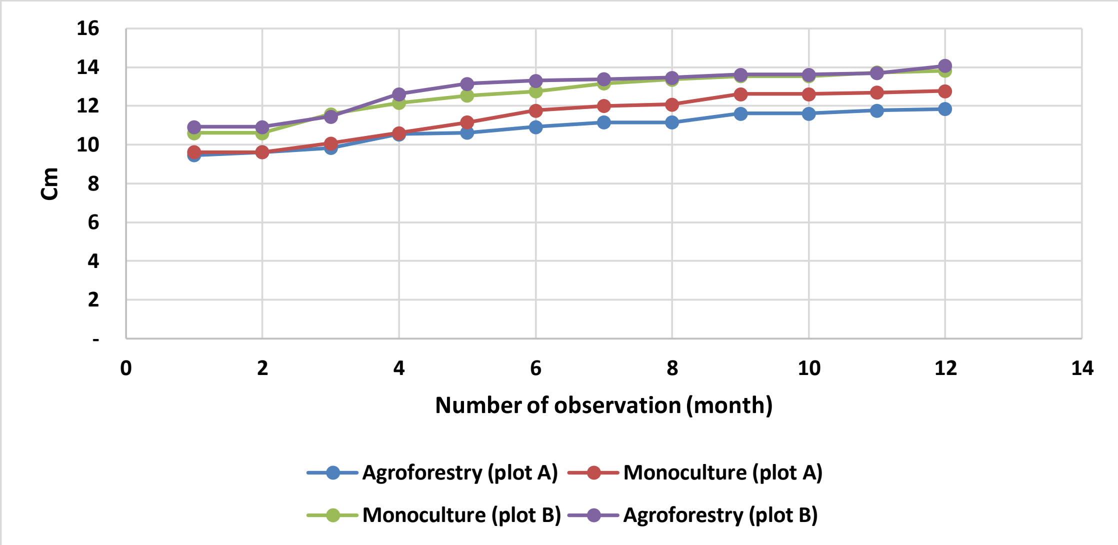

Figure 8. Circular stem growth of kemiri sunan in monoculture vs. agroforestry plots in Buntoi reseaech site in Central Kalimantan.

Our wilcoxon rank sum test further shows that nyamplung performs better for both tree height and circular stem growth as compared to kemiri sunan (Figures 9 and 10). 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).

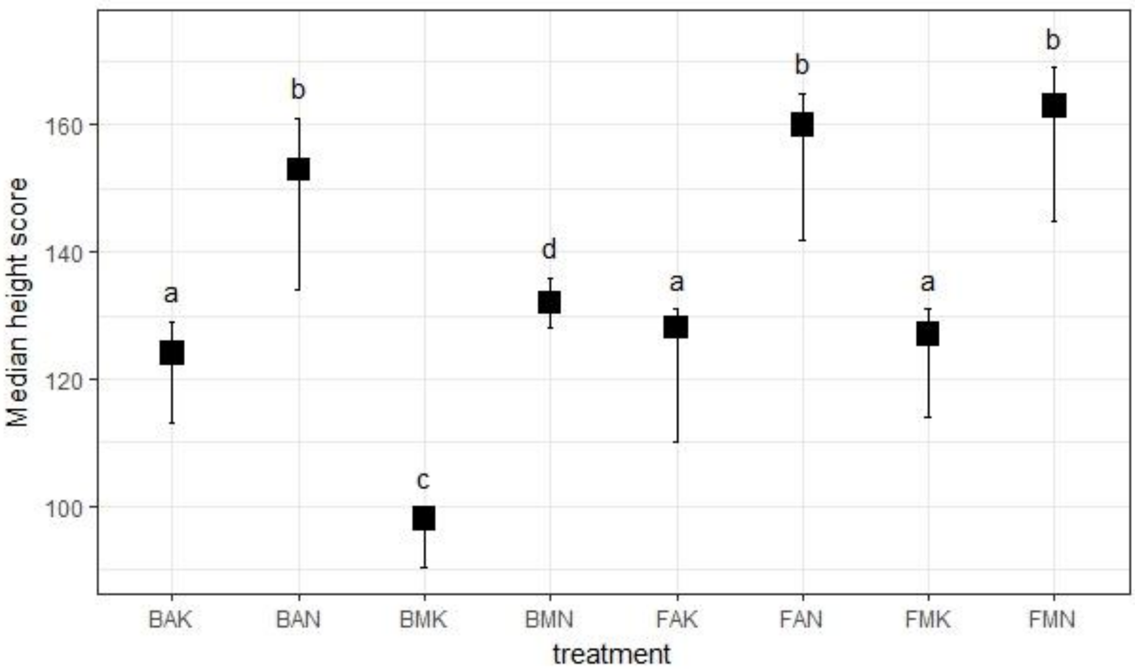

Figure 9. Results of Wilcoxon rank sum test on tree height for nyamplung and kemiri sunan (BAK—agroforestry kemiri sunan plot B; BAN—agroforestry nyamplung plot B; BMK—monoculture kemiri sunan plot B; BMN—monoculture nyamplung plot B; FAK—agroforestry kemiri sunan plot A; FAN—agroforestry nyamplung plot A; and, 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.

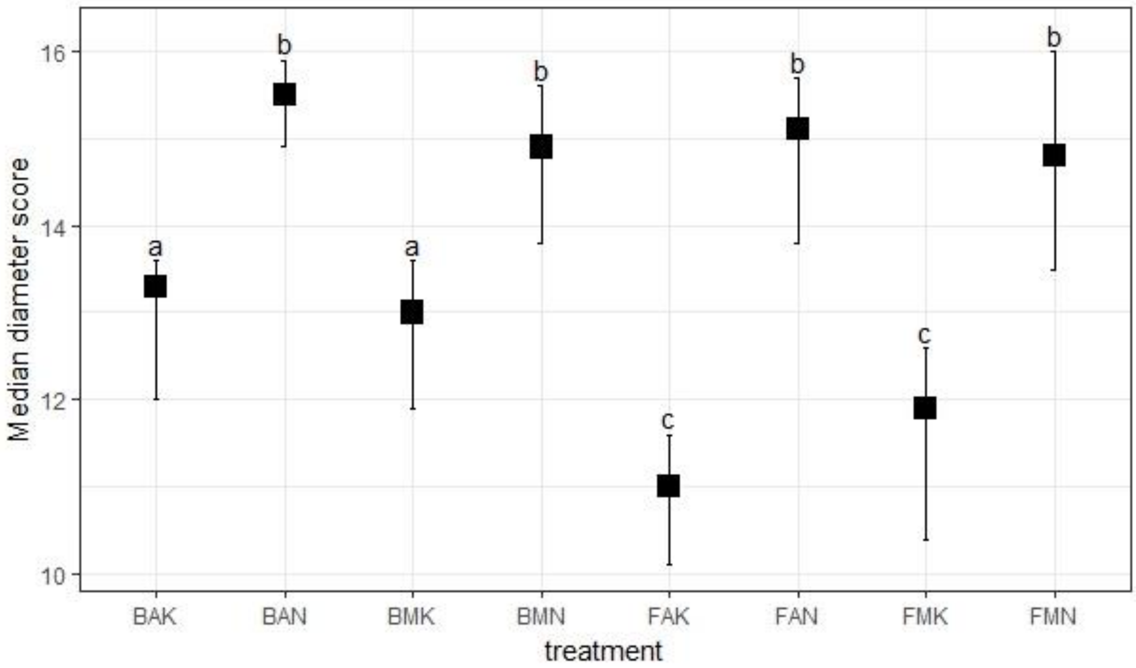

Figure 10. Results of Wilcoxon rank sum test on tree diameter for nyamplung and kemiri sunan (BAK—agroforestry kemiri sunan plot B; BAN—agroforestry nyamplung plot B; BMK—monoculture kemiri sunan plot B; BMN—monoculture nyamplung plot B; FAK—agroforestry kemiri sunan plot A; FAN—agroforestry nyamplung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

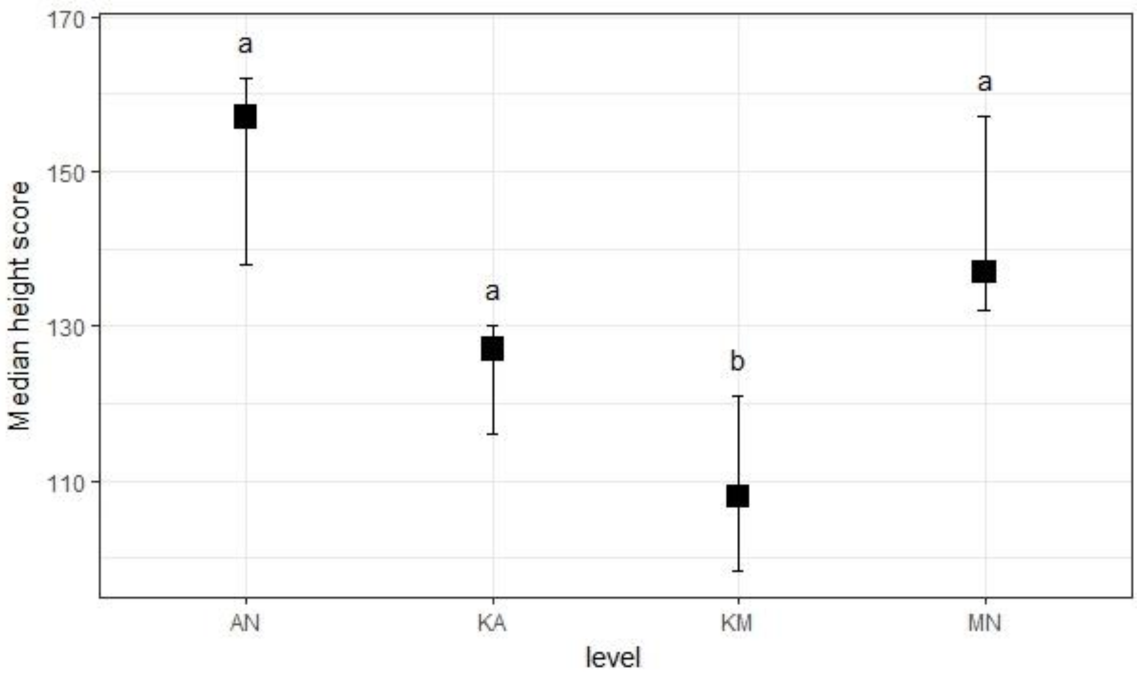

Figure 11. Results of Wilcoxon rank sum test on tree height under two different treatments, i.e., agroforestry and monoculture, for nyamplung and kemiri sunan (AN—agroforestry nyamplung; KA—agroforestry kemiri sunan; KM—monoculture kemiri sunan; and, MN—monoculture nyamplung). The letters a and b on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

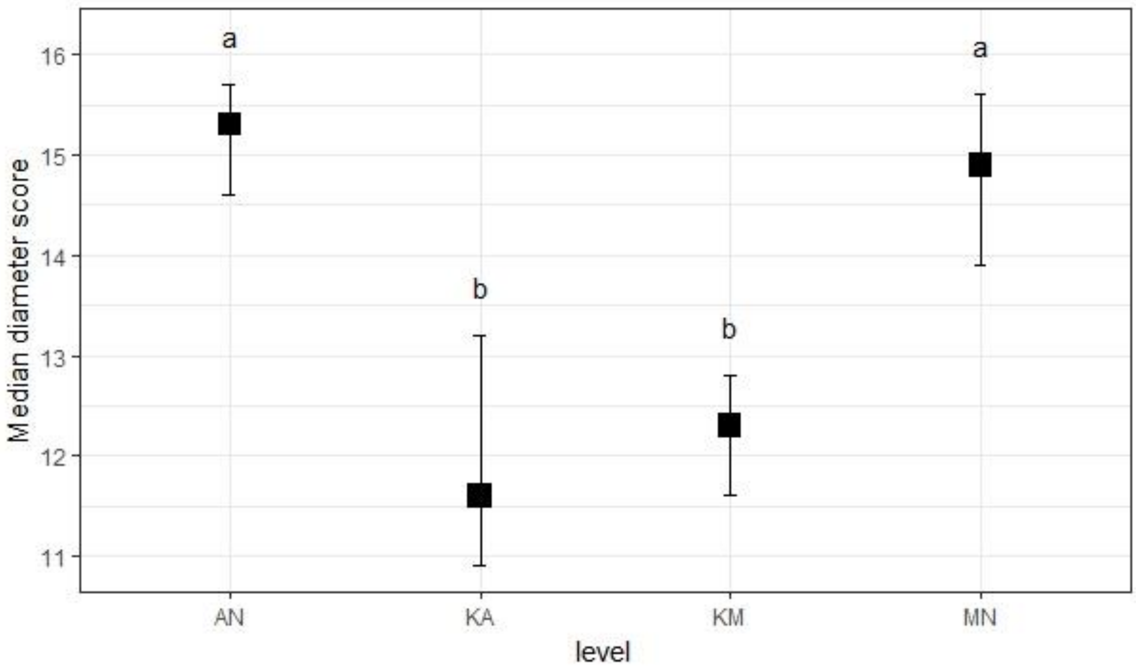

Figure 12. Results of Wilcoxon rank sum test on tree diameter under two different treatments, i.e., agroforestry and monoculture, for nyamplung and kemiri sunan (AN—agroforestry nyamplung; KA—agroforestry kemiri sunan; KM—monoculture kemiri sunan; and, MN—monoculture nyamplung). The letters a and b on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

Our research shows that out of four tested species, nyamplung is the most adoptable species, followed by kemiri sunan, when grown on burned and degraded peatland in Central Kalimantan. However, both species performed very well under agroforestry treatment when compared to 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 [37,41–45]. If the target is also to motivate local farmers to use their degraded land for biofuel production, it is important to consider that tree growing by farmers is often associated with multiple objectives influenced by livelihood necessities and local cultures [46–49]. Current literature emphasizes that farmers' capacity to adopt tree planting is also dependent on production technology, adequate physical infrastructure, and developed markets for tree products [47,49,50]. 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 [51].

Planting millions of square miles of biofuel could store between 1.2 and 6.3 billion tons of carbon/year; enough to make a very large dent in global greenhouse gas emissions [52], while also providing sufficient energy stock [53]. However, there is a risk that doing so could lead to forest clearance, compete with agricultural production and put additional pressure on biodiversity [52]. As a solution, producing biofuel on degraded land can avoid compromising agricultural production and the related negative environmental consequences.

4. Conclusions

This study demonstrated that among four trial species, nyamplung is the most adaptive (88%) bioenergy species for growth on degraded peatland in Central Kalimantan, followed by kemiri sunan (48%). Growth performance indicators showed that nyamplung grew better in agroforestry sub-plots when compared to monoculture sub-plots both in terms of height and circular stem 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 performance using agroforestry, can promote the benefits of agroforestry and enhance farmers' livelihoods, as well as supporting sustainable development. However, further study on the productivity and associate biofuel yields of both species is needed. Further studies are also needed for these four selected, and 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, with more controlled environment. That may help to get additional data, such as in our study it was not clear why there are significant differences between the same species and the same treatment (e.g., Figure 9). Selecting tree species with multiple benefits in terms of livelihoods, local culture familiarity, and strong market value, might be beneficial to improve farmers' motivation to utilize degraded land for biofuel production.

Author Contributions: S.M., H.B., Y.A. and S.M.L. designed the study. S.M. and Y.B.S. collected the data. S.A.R., Y.A. and T.I.S. prepared, analyzed and interpreted the data. Y.B.S. and S.A.R. collected the data and reviewed the literature. S.M., S.A.R., Y.A. and H.B. prepared and reviewed the manuscript. All the authors read and approved the final manuscript.

Funding: The funding partners that have supported this research include the CGIAR Research Program on Forests, Trees and Agroforestry (CRP-FTA) with financial support from the donors that support the CGIAR Fund, and the National Institute Forest Sciences, Korea.

Acknowledgments: Authors are grateful to the field assistants, graduate students and researchers from the Natural Universitas Muhammadiyah Palangkaraya, Central Kalimantan, Indonesia, as well as to colleagues at CIFOR who provided their assistance, time and thoughtful scientific support for this research.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A

Table A1. Environmental requirements for four tested bioenergy species.

Species	Mean Annual Temperature (°C)		Mean Annual Rainfall (mm)		Source
	Min	Max	Min	Max	
Gamal	20	27	600	3500	53
Kaliandra	22	28	700	4000	54
Kemiri sunan	18	30	700	2500	55

References

1. IEA (International Energy Agency). *Indonesia 2015—Energy Policies beyond IEA Countries*; IEA: Paris, France, 2015.
2. Firdaus, Y.; Mukhtasor; Suroso, A. Analysis of an effect of oscillating part transformation in vortex energy conversion using a numerical model. *J. Kelaut. Nas.* **2011**, *6*, 1–12.
3. GOI (Government of Indonesia). *PP No. 79 Thn 2014*; GOI: Jakarta, Indonesia, 2014.
4. Nijsen, M.; Edward, S.; Elke, S.; Detlef, P.V. An evaluation of the global potential of bioenergy production on degraded lands. *GCB Bioenergy* **2012**, *4*, 130–147. [CrossRef]
5. Campbell, J.E.; David, B.L.; Robert, C.G.; Christopher, B.F. The global potential of bioenergy on abandoned agricultural lands. *Environ. Sci. Technol.* **2008**, *42*, 5791–5794. [CrossRef] [PubMed]
6. Fargione, J.; Hill, J.; Tilman, D.; Polasky, S. Land clearing and the biofuel carbon debt. *Science* **2008**, *319*, 1235–1238. [CrossRef] [PubMed]
7. Borchard, N.; Bulusu, M.; Hartwig, A.M.; Ulrich, M.; Lee, S.M.; Baral, H. Screening potential bioenergy production of tree species in degraded and marginal land in the tropics. *Forest.* **2018**, *9*, 594. [CrossRef]
8. ICCC (Indonesia Climate Change Center). *Crop to Energy on Degarded Land as a Step toward Energy Independence, Carbon Sink, Agriculture and Protection of REDD+ Designated Areas*; ICCC: Jakarta, Indonesia, 2014.

9. Suwarno, A. Optimising Land Use in Central Kalimantan Province, Indonesia: Modeling Ecosystem Benefits and Land Use Dynamics. Ph.D. Thesis, Wageningen University, Wageningen, The Netherlands, 2016.
10. Abood, S.A.; Lee, J.S.H.; Burivalova, Z.; Garcia-Ulloa, J.; Koh, L.P. Relative contributions of the logging, fiber, oil palm, and mining industries to forest loss in Indonesia. *Conserv. Lett.* **2015**, *8*, 58–67. [CrossRef]
11. Medrilzam, M.; Dargusch, P.; Herbohn, J.; Smith, C. The socio-ecological drivers of forest degradation in part of the tropical peatlands of Central Kalimantan, Indonesia. *Forestry* **2014**, *87*, 335–345. [CrossRef]
12. Page, S.E.; Siegert, F.; Rieley, J.O.; VanBoehm, H.D.; Jaya, A.; Limin, S. The amount of carbon released from peat and forest fires in Indonesia during 1997. *Nature* **2002**, *420*, 61–65. [CrossRef] [PubMed]
13. Carlson, K.M.; Curran, L.M.; Asner, G.P.; Pittman, A.M.; Trigg, S.N.; Adeney, J.M. Carbon emissions from forest conversion by Kalimantan oil palm plantations. *Nat. Clim. Chang.* **2013**, *3*, 283–287. [CrossRef]
14. GGGI (Global Green Growth Institute). Renewable Energy Options in Kalimantan: A Green Growth Assessment. 2015. Available online: http://gggi.org/site/assets/uploads/2017/12/GGGI%E2%80%99s-Technical-Guidelines-on-Green-Energy-Development_dereje-senshaw2017.pdf (accessed on 27 March 2018).
15. IRENA (International Renewable Energy Agency). *Renewable Energy Prospects: Indonesia, a REmap Analysis*; IRENA: Abu Dhabi, UAE, 2017.
16. Rony. Kabupaten Di Kalteng Jadi Percontohan Bioenergi. 2015. Available online: https://kalteng.antaranews.com/berita/245678/2-kabupaten-di-kalteng-jadi-percontohan-bioenergi (accessed on 27 March 2018).
17. Buntoi Village Administration. *Buntoi Village, Pulang Pisau District, Central Kalimantan Province, Indonesia*; Government of Indonesia: Jakarta, Indonesia, 2017.
18. Abram, N.K.; Meijaard, E.; Wilson, K.A.; Davis, J.T.; Wells, J.A.; Ancrenaz, M.; Budiharta, S.; Durrant, A.; Fakhruzzi, A.; et al. Oil palm-community conflict mapping in Indonesia: A case for better community liaison in planning for development initiatives. *Appl. Geol.* **2017**, *78*, 33–44. [CrossRef]
19. Gaveau, D.L.A.; Sheil, D.; Husnayaen; Salim, M.A.; Arjasakusuma, S.; Ancrenaz, M.; Pacheco, P.; Meijaard, E. Rapid conversions and avoided deforestation: Examining four decades of industrial plantation expansion in Borneo. *Sci. Rep.* **2016**. [CrossRef] [PubMed]
20. Vijay, V.; Pimm, S.L.; Jenkins, C.N.; Smith, S.J. The Impacts of oil palm on recent deforestation and biodiversity loss. *PLoS ONE* **2016**. [CrossRef] [PubMed]
21. Leksono, B.; Windyarini, E.; Hasnah, T.M. *Budidaya Tanaman Nyamplung (Calophyllum Inophyllum) Untuk Bioenergi Dan Prospek Pemanfaatan Lainnya*; IPB Press: Jakarta, Indonesia, 2014.
22. Agoramoorthy, G.; Sarnaik, J.; Mungikar, R.; Punde, S.; Hsu, M.J. Non-edible oil seed producing Calophyllum inophyllum ideal for India's future biofuel development. *GCB Bioenergy* **2012**, *4*, 708–712. [CrossRef]
23. Ong, H.C.; Mahlia, T.M.I.; Masjuki, H.H.; Norhasyima, R.S. Comparison of palm oil, Jatropha curcas and Calophyllum inophyllum for biodiesel: A review. *Renew. Sustain. Energy Rev.* **2011**, *15*, 3501–3515. [CrossRef]
24. Orwa, C.; Mutua, A.; Kindt, R.; Jamnadass, R.; Anthony, S. *Calliandra Calothyrsus. Agroforestry Database 4.0*; ICRAF: Nairobi, Kenya, 2009.
25. Palmer, B.; Macqueen, D.; Gutteridge, R. Calliandra calothyrsus—A multipurpose tree legume for humid locations. In *Forage Tree Legumes in Tropical Agriculture*; Gutteridge, R., Shelton, M., Eds.; CAB Interactional: Wallingford, UK, 1994; pp. 1–9.
26. Hamim, H.; Hilmi, M.; Pranowo, D.; Saprudin, D.; Setyaningsih, L. Morpho-physiological changes of biodiesel producer plants reutealis trisperma (Blanco) in response to gold-mining wastewater. *Pak. J. Biol. Sci.* **2017**, *20*, 423–435. [CrossRef] [PubMed]
27. Bhattacharya, S.; Salam, P.A.; Pham, H.; Ravindranath, N. Sustainable biomass production for energy in selected Asian countries. *Biomass Bioenergy* **2003**, *25*, 471–482. [CrossRef]
28. Mainoo, A.A.; Ulzen-Appiah, F. Growth, wood yield and energy characteristics of Leucaena Leucocephala, Gliricidia Sepium and Senna Siamea at age four years. *Ghana J. For.* **1996**, *3*, 54–76.
29. Arun, V.V.; Saharan, N.; Ramasubramanian, V.; Rani, A.M.B.; Salin, K.R.; Sontakke, R.; Haridas, H.; Pazhayamadom, D.G. Multi-response optimization of artemia hatching process using split-split-plot design based response surface methodology. *Sci. Rep.* **2017**, *7*, 40394. [CrossRef] [PubMed]
30. Perry, M.B.; Gary, R.M.; James, R.S. On the analysis of balanced two-level factorial whole-plot saturated split-plot designs. *Qual. Reliab. Eng. Int.* **2013**, *29*, 327–343. [CrossRef]
31. Zi, X.M.; Runchu, Z.; Min, Q.L. On optimal two-level nonregular factorial split-plot designs. *J. Complex.* **2012**, *28*, 459–467. [CrossRef]

32. Orwa, C.; Mutua, A.; Kindt, R.; Jamnadass, R.; Anthony, S. Agroforestree Database: A Tree Reference and Selection Guide Version 4.0. 2009. Available online: http://www.worldagroforestry.org/publication/agroforestree-database-tree-species-reference-and-selection-guide-version-40 (accessed on 3 November 2018).
33. Hendrati, R.L.; Hidayati, N. *Budidaya Kaliandra (Calliandra Calothyrsus) Untuk Bahan Baku Sumber Energi*; Na'iem, M., Mahfudz, Prabawa, S.B., Eds.; IPB Press: Jakarta, Indonesia, 2014.
34. Hudaedi, D.; Studi, P.; Sumberdaya, P. Potensi Gamal (Gliricidia sepium) Sebagai Bahan Baku Pembangkit Listrik Tenaga Biomassa Studi Kasus: Kabupaten Manggarai Timur (NTT). *J. Environ. Eng. Waste Manag.* **2018**, *3*, 13–20.
35. Leksono, B.; Hendrati, R.L.; Windyarini, E.; Hasnah, T. Variation in Biofuel Potential of Twelve Calophyllum Inophyllum Populations in Indonesia. Indones. *J. For. Res.* **2014**, *1*, 127–138. [CrossRef]
36. Pranowo, D.; Herman, M. Syafaruddin Potensi Pengembangan Kemiri Sunan (Reutealis trisperma (Blanco) Airy Shaw) Di Lahan Terdegredasi. *Perspektif* **2015**, *14*, 87–102. [CrossRef]
37. Dagar, J.C.; Singh, A.K.; Arunachalam, A. Introduction. In *Agroforestry Systems in India: Livelihood Security & Ecosystem Services*; Advances in Agroforestry Series; Dagar, J.C., Singh, A.K., Arunachalam, A., Eds.; Springer: Dordrecht, The Netherlands, 2014; Volume 10, pp. 1–19.
38. Scott, P.T.; Pregelj, L.; Chen, N.; Hadler, J.S.; Djordjevic, M.A.; Gresshoff, P.M. Pongamia pinnata: An untapped resource for the biofuels industry of the future. *Bioenergy Res.* **2014**, *1*, 2–11. [CrossRef]
39. Restuaji, I.M.; Santoso, E. Pengaruh penambahan karbon aktif terhadap reaksi transesterifikasi minyak kemiri sunan (aleurites trisperma) yang sudah diperlakukan dengan kitosan. *J. Sains Dan Seni Pomits* **2014**, *1*, 1–12.
40. Herman, M.; Syakir, M.; Pranowo, D.; Saefudin, S. *Kemiri Sunan (Reutealis trisperma (Blanco) Airy Shaw) Tanaman Penghasil Minyak Nabati Dan Konservasi Lahan*; IAARD Pr: Jakarta, Indonesia, 2013.
41. Rahman, S.A.; Rahman, M.F.; Sunderland, T. Increasing tree cover in degrading landscapes: 'Integration' and 'intensification' of smallholder forest culture in the Alutilla valley, Matiranga, Bangladesh. *Small-Scale For.* **2014**, *13*, 237–249. [CrossRef]
42. Idol, T.; Haggar, J.; Cox, L. Ecosystem services from smallholder forestry and agroforestry in the tropics. In *Integrating Agriculture, Conservation and Ecotourism: Examples from the Field, Issues in Agroecology—Present Status and Future Prospectus*; Campbell, W.B., Ortiz, S.L., Eds.; Springer: Dordrecht, The Netherlands, 2011; Volume 1, pp. 209–270.
43. Leakey, R.R.B. Agroforestry: A delivery mechanism for multi-functional agriculture. In *Handbook on Agroforestry: Management Practices and Environmental Impact, Environmental Science, Engineering and Technology Series*; Kellimore, L.R., Ed.; Nova Science Publishers: Hauppauge, NY, USA, 2010; pp. 461–471.
44. Roshetko, J.M.; Snelder, D.J.; Lasco, R.D.; van Noordwijk, M. Future challenge: A paradigm shift in the forestry sector. In *Smallholder Tree Growing for Rural Development and Environmental Services: Lessons from Asia. Advances in Agroforestry Series*; Snelder, D.J., Lasco, R.D., Eds.; Springer: Dordrecht, The Netherlands, 2008; Volume 5, pp. 453–485.
45. Garrity, D.P. Agroforestry and the achievement of millennium development goals. *Agrofor. Syst.* **2004**, *61*, 5–17. [CrossRef]
46. Rahman, S.A.; Rahman, M.F.; Sunderland, T. Causes and consequences of shifting cultivation and its alternative in the hill tracts of eastern Bangladesh. *Agrofor. Syst.* **2012**, *84*, 141–155. [CrossRef]
47. Rahman, S.A.; de Groot, W.; Snelder, D.J. Exploring the agroforestry adoption gap: Financial and socioeconomics of litchi-based agroforestry by smallholders in Rajshahi (Bangladesh). In *Smallholder Tree Growing for Rural Development and Environmental Services: Lessons from Asia. Advances in Agroforestry Series*; Snelder, D.J., Lasco, R.D., Eds.; Springer: Dordrecht, The Netherlands, 2008; Volume 5, pp. 227–244.
48. Schuren, S.H.G.; Snelder, D.J. Tree growing on farms in Northeast Luzon (The Philippines): Smallholders' motivations and other determinants for adopting agroforestry systems. In *Smallholder Tree Growing for Rural Development and Environmental Services: Lessons from Asia. Advances in Agroforestry Series*; Snelder, D.J., Lasco, R.D., Eds.; Springer: Dordrecht, The Netherlands, 2008; Volume 5, pp. 75–97.
49. van Noordwijk, M.; Roshetko, J.M.; Murniati Angeles, M.D.; Suyanto Fay, C.; Tomich, T.P. Farmer tree planting barriers to sustainable forest management. In *Smallholder Tree Growing for Rural Development and Environmental Services: Lessons from Asia. Advances in Agroforestry Series*; Snelder, D.J., Lasco, R.D., Eds.; Springer: Dordrecht, The Netherlands, 2008; Volume 5, pp. 429–451.

50. Snelder, D.J.; Lasco, R.D. Smallholder tree growing in South and Southeast Asia. In *Smallholder Tree Growing for Rural Development and Environmental Services: Lessons from Asia. Advances in Agroforestry Series*; Snelder, D.J., Lasco, R.D., Eds.; Springer: Dordrecht, The Netherlands, 2008; Volume 5, pp. 3–33.
51. Franzel, S.; Scherr, S.J. Introduction. In *Trees on the Farm: Assessing the Adoption Potential of Agroforestry Practices in Africa*; Franzel, S., Scherr, S.J., Eds.; CABI: Wallingford, UK, 2002; pp. 1–11.
52. Mooney, C. It's the Big New Idea for Stopping Climate Change, But It Has Huge Environmental Problems of Its Own. Available online: https://www.washingtonpost.com/news/energy-environment/wp/2018/01/22/a-technology-many-hoped-would-fight-climate-change-would-cause-even-bigger-environmental-problems-scientists-say/?noredirect=on&utm_term=.0defcd729713 (accessed on 31 May 2018).
53. Baral, H.; Lee, S.M. *Sustainable Bioenergy Systems to Restore and Valorize Degraded Land*; CIFOR Brief No. 37. Center for International Forestry Research (CIFOR): Bogor, Indonesia, 2016.
54. CABI. Invasive Species Compendium. 2018. Available online: https://www.cabi.org/isc/datasheet/25380 (accessed on 24 September 2018).
55. CABI. Invasive Species Compendium. 2018. Available online: https://www.cabi.org/ISC/datasheet/14011 (accessed on 24 September 2018).
56. CABI. Invasive Species Compendium. 2018. Available online: https://www.cabi.org/ISC/datasheet/4125 (accessed on 24 September 2018).
57. CABI. Invasive Species Compendium. 2018. Available online: https://www.cabi.org/ISC/datasheet/14124 (accessed on 24 September 2018).