

Tropical secondary forest of East Kalimantan, Indonesia: diversity of plant species and its biomass potency for sustainable green energy production

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Tropical secondary forest of East Kalimantan, Indonesia: diversity of plant species and its biomass potency for sustainable green energy production

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ABSTRACT

In this paper, an attempt was made to find out the diversity, productivity and suitability of plant species in the secondary forests of East Kalimantan, Indonesia which has the potential to be used as high-quality feedstock for sustainable green energy production. Diversity of plant species was studied by making 22 plots with the size of 20 m x 20 m located at secondary forest of Mahakam Ulu, East Kalimantan, Indonesia. The importance value index of plant species found was calculated using the equation of Mueller-Dombois and Ellenberg. The physico-chemical properties and elemental composition of wood biomass collected were determined using the method of American Standards for Testing and Material (ASTM). We found 57 species which belongs of 28 families were growing in the secondary forest area. Among them, the highest Important Value Index (IVI) was Lamiaceae, *Vitex pinnata* (32.72%). *V. pinnata* was also achieved the highest calorific value of 18.00 MJ kg⁻¹. Due to suitable energy properties, growth rate and also adaptability of the woody biomass, a secondary forest plant species, *V. pinnata* was recognized as the important species among all other species observed because of its high adaptability and energy content.

Key words : Biomass, Diversity, Green energy, Tropical forest, *Vitex pinnata*

Introduction

Nowadays, the concerns related to energy production from fossil fuels and associated environmental impacts are increasing. The issue of CO₂ emission from burning of fossil fuels and global warming is being discussed seriously in many developed and developing countries (Han and Shin, 2014; Kumar *et al.*, 2015; Garcia and Bacenetti, 2019). Indonesia and many other national governments that are facing a

serious problem on energy supply have declared to start production of energy and fuels from renewable sources, mainly biomass (biofuels). Currently, biomass is known as a renewable energy source which is considered as almost carbon neutral (Bilandzija *et al.*, 2018). In term of this, it has been fundamental now to provide energy by biomass for the development of civilization, especially for the rural and remote areas that commonly have huge biomass resources.

East Kalimantan province as a part of Indonesia has vast areas of remote area and forest land with a high diversity of plant species. Massive wood biomass and other materials are produced here in various types of forest lands, such as low land forests, primary forests and also secondary forests. These forest materials consist of potential biomass feedstock for green energy production (Amirta *et al.*, 2016a, 2016b, 2019; Yuliansyah and Amirta, 2016; Haqiqi *et al.*, 2018). Understanding of the species diversity and richness, biomass productivity and its suitability to be used as the green energy feedstock is important not only for the sustainable supply of biomass-based energy for the community, but also for conserving and managing the tropical secondary forest itself. Therefore, here in the study diversity of plants and the potential of biomass from tropical secondary forest was investigated to point out their suitability to be used as feedstock for sustainable green energy production.

Materials and Methods

Study area

This study was conducted in the secondary forest area of Batu Majang Village, District of Mahakam Ulu, East Kalimantan Province, Indonesia (115°12'17.550" E, 0°33'3.039" N). This village has an area of about 29.377 ha and annual temperature of 25-34°C, while the daily temperatures fluctuate between 3-4°C. The mean annual precipitation was 4,026 mm, whereas the highest monthly rainfall was obtained in April and the lowest occurs in August amounted to 242 mm, respectively.

Diversity of plant species

Diversity of plant species of secondary forest was studied by making 22 plots with the size of 20 m x 20 m. The importance value index of plant species found at the research area was calculated using equation of Mueller-Dombois and Ellenberg as described and reported by (Wiryo *et al.*, 2016). Further, biomass in the form of leaves, stem and branches of tree and woody shrub species with diameter about 5-10 cm were collected. Then, the leaves and branches of each species deposited and identified at Laboratory of Dendrology and Forest Ecology, Faculty of Forestry, Mulawarman University for further analysis to recognize the scientific name of the species. In addition, wood samples

were debarked, chipped, air dried, and used throughout this study.

Physico-chemical properties and elemental composition of wood biomass

The physico-chemical properties of the collected wood biomass from post shifting cultivation area (fallow period) were determined according to the method of American Standard for Testing and Material (ASTM) D 7582-12: moisture content, ash, volatile matter and fixed carbon. The various parameters analyzed consist of moisture content, ash value, density, volatile matter and fixed carbon tests. In addition, to determine the elemental composition of wood biomass such as carbon (C), hydrogen (H) and oxygen (O), and to find out the higher calorific value (HCV), the protocols proposed by [6,7] was used.

Results and Discussion

Diversity of plant species

A total of 57 biomass plant species were found in the secondary forest area studied. The research plot resulted consisting of trees and woody shrubs in which belong to 28 families. Those plant species were identified as *Aglaia edulis* (Roxb.) Wall., *Alseodaphne* sp., *Antidesma* sp., *Aquilaria* sp., *Artocarpus* sp., *Artocarpus elasticus* Reinw. ex Blume, *Bridelia tomentosa*, *Bridelia glauca* Blume, *Callicarpa longifolia* Lam., *Canarium denticulatum*, *Cratoxylum sumatranum* (Jack) Blume, *Cratoxylum formosum* (Jacq.) Benth. and Hook.f. ex Dyer, *Croton argyrateus* Blume, *Cyathocalyx* sp., *Dacryodes* sp., *Dipterocarpus borneensis* Slooten, *Duabangagrandiflora* (DC.) Walp., *Dyera costulata* (Miq.) Hook.f., *Ficus uncinata* (King) Becc., *Ficus aurata* (Miq.) Miq., *Garcinia* sp., *Gironniera nervosa* Planch., *Glochidion obscurum* (Roxb. ex Willd.) Blume, *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg., *Ixonanthes reticulata* Jack, *Kleinhovia hospita* L., *Knema glauca* (Blume) Petermann, *Koompassiamalaccensis* Benth., *Leucaena leucocephala*, *Lithocarpus gracilis* (Korth.) Soepadmo, *Litsea elliptica* Blume, *Macaranga gigantea* (Rchb.f. & Zoll.) Müll.Arg., *Macaranga hypoleuca* (Rchb.f. & Zoll.) Müll.Arg., *Macaranga lowii* King ex Hook.f., *Macaranga pearsonii* Merr., *Macaranga triloba* (Thunb.) Müll.Arg., *Macaranga umbrosa* S.J.Davies, *Madhuca kingiana*, *Madhuca* sp., *Melicope hookeri* T.G.Hartley, *Neonauclea gigantea* (Valeton) Merr.,

Neolamarckia cadamba (Roxb.) Bosser, *Piper aduncum* L., *Polyscias* sp., *Pternandra cogniauxii* M.P.Nayar, *Pternandra* sp., *Pterospermum javanicum* Jungh., *Quercus* sp., *Santiria longifolia*, *Shorea guiso* Blume, *Shorea ovalis* Blume, *Shorea leprosula* Miq., *Shorea laevis*, *Syzygium polyanthum* (Wight) Walp., *Tremaorientalis* (L.) Blume, *Tristania* sp., and *Vitex pinnata* L.

In the present study, we found *V. pinnata* (Lamiaceae) was the highest dominant of forest plant species in the secondary forest area studied and it was indicated by the highest importance value index of 32.72 from the total population in the area, and followed by *N. gigantea*, 13.59 (Rubiaceae) and *M. pearsonii*, 13.15 (Euphorbiaceae) (Table 1). Inline with this finding, *V. pinnata* was reported as dominant species that could be easily found in secondary forest of Borneo Island and traditionally used by local people as firewood and medicinal plant, especially for skin treatment (Kiyono and Hastaniah, 2008; Goh *et al.* 2017; Arung *et al.* 2017, 2018). Further, we found the Shannon-Wiener index value of the secondary forest plant species in this study was 3.3. In general discussion, diversity of plant species in this study area could be classified into the middle diversity level. The results also showed that Euphorbiaceae was found as the other

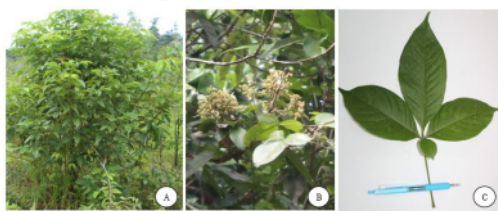


Fig. 1. (A) Shrub, (B) flower, and (C) leaf shape of *Vitex pinnata* (Lamiaceae)

dominant and important family in the secondary forest area according to the highest importance value index measured. The important family of Euphorbiaceae was represented by the presence of *M. pearsonii*, *M. triloba*, *M. hypoleuca* and also *H. brasiliensis* with importance value index were 13.15, 12.63, 10.23 and 10.12, respectively (Table 1).

Inline with this finding, Kenzo *et al.* (2010) reported that Macaranga, Artocarpus and Ficus are common plant species observed in regenerated secondary forest area after abandonment. Macaranga was also reported as the pioneer plant species that usually grow sporadically on the gap of forest canopy, degraded land, disturbed areas after forest fire or opening area for the shifting cultivation (Slik *et al.*, 2003; Crepaldi *et al.*, 2016). Moreover, shrub and tree species such as Macaranga was also traditionally used by Dayak people and local farmers in East Kalimantan as the natural key plant species indicator to determine the end of the recovery period of forest land after ground fire or shifting cultivation activities (Imang *et al.*, 2008; Susanto *et al.* 2016; Amirta *et al.*, 2016a, 2016b).

Physico-chemical properties and elemental composition of wood biomass

The results from laboratory analysis demonstrated that conversion of wood stem into chip (wood chip) was successfully reduced the amount of water in wood samples. Most of moisture contents of woody biomass were lower than those of green wood condition as shown in Table 2. Low moisture content is important for wood as suitable solid fuel for thermochemical conversion into energy (McKendry, 2002; Parikh *et al.*, 2005).

Furthermore, we also found that wood biomass

Table 1. The top 10 plant species based on their importance value index in the secondary forest area studied

Plant species	Family	Local name	RDo	RF	RDe	IVI
<i>Vitex pinnata</i>	Lamiaceae	Temaa	4.4	5.94	22.4	32.72
<i>Neonauclea gigantea</i>	Rubiaceae	Tembalut	3.6	2.97	7.0	13.59
<i>Macaranga pearsonii</i>	Euphorbiaceae	Benuaq	2.5	4.95	5.7	13.15
<i>Macaranga triloba</i>	Euphorbiaceae	Benuaq putih	4.7	3.96	3.9	12.63
<i>Litsea elliptica</i>	Lauraceae	Uampak	7.6	1.98	0.9	10.48
<i>Knema glauca</i>	Myristicaceae	Penjalin batu	7.1	1.98	1.3	10.43
<i>Macaranga hypoleuca</i>	Euphorbiaceae	Benuaq putih	3.2	3.96	3.1	10.23
<i>Lithocarpus gracilis</i>	Fagaceae	Palan	5.1	2.97	2.2	10.23
<i>Hevea brasiliensis</i>	Euphorbiaceae	Karet	2.8	2.97	4.4	10.12
<i>Ficus uncinata</i>	Moraceae	Abong	0.4	2.97	5.7	9.03

Note: RDo: Relative Dominance; RF: Relative Frequency; RDe: Relative Density; IVI: Importance Value Index

from *V. pinnata* was achieved the highest calorific value (18.00 MJ kg⁻¹). Moreover, *M. triloba*, *L. gracilis*, and *H. brasiliensis* were the second and third place with the value of 17.11 MJ kg⁻¹ and 16.93 MJ kg⁻¹, respectively. The results were fitted well with the local knowledge and function of woody biomass, whereas those of woody species were traditionally used as firewood. Inline with the result previously reported that nearly all households in forest area depend on firewood as their main source of fuel (Dalle and De Blois, 2006).

Then, from proximate analysis we found the average value of volatile matter was 69.39%, fixed carbon 16.88% and ash content 1.70% (Table 3). Composition of volatile matter and fixed carbon also affects high heating value causing flame stability during combustion (Virmond *et al.*, 2012). Low ash proportion (<5%) allows wood biomass to be suitable feedstock for thermal utilization. In contrast, high ash content causes high dust emissions and nega-

tively affects combustion efficiency (Ivanova *et al.*, 2018). Moreover, the results from ultimate analysis was demonstrated that the average value of carbon, hydrogen and oxygen contents of wood biomass was 43.21%, 5.52%, and 46.60%, respectively (Table 3). The average of carbon, hydrogen and oxygen contents of plant biomass collected in the current study indicate that they belong to good quality of fuel biomass, and suitable to be used as green energy feedstock. Wood biomass could be used as fuel/green energy when the carbon content varied between 30-60%, 5-6% of hydrogen, 30-40% of oxygen, and the other elements are less than 1%, respectively (Ivanova *et al.*, 2018).

Conclusion

Based on those findings and discussion, we concluded that *V. pinnata* was the greatest species due to its high adaptability to grow well at secondary

Table 2. Physical properties and calorific value of wood biomass species from the top 10 highest importance value index of plant species in the secondary forest area studied

Species	Moisture content (greenwood) (%)	Moisture content (wood chip) (%)	Wood density (g cm ⁻³)	Calorific value (MJ kg ⁻¹)
<i>V. pinnata</i>	21.43	8.57	0.55	18.00
<i>N. gigantea</i>	69.62	15.14	0.48	16.90
<i>M. pearsonii</i>	33.94	11.72	0.26	16.58
<i>M. triloba</i>	33.85	10.33	0.36	17.11
<i>L. elliptica</i>	61.64	12.73	0.37	16.30
<i>K. glauca</i>	48.11	10.06	0.53	16.26
<i>M. hypoleuca</i>	44.73	10.39	0.27	16.14
<i>L. gracilis</i>	21.74	11.14	0.68	16.93
<i>H. brasiliensis</i>	39.80	9.16	0.61	16.93
<i>F. uncinata</i>	60.27	9.40	0.56	15.44

Table 3. Proximate and ultimate analysis of wood biomass species with the highest importance value index of plant species in the secondary forest area studied

Species	Proximate (%)			Ultimate (%)		
	Volatile matter	Fixed carbon	Ash content	Carbon	Hydrogen	Oxygen
<i>V. pinnata</i>	71.67	19.32	1.04	43.29	5.86	50.725
<i>N. gigantea</i>	69.59	14.49	0.79	45.34	5.19	37.53
<i>M. pearsonii</i>	69.49	16.30	2.60	43.88	5.69	50.41
<i>M. triloba</i>	71.07	17.08	1.14	44.85	5.87	49.22
<i>L. elliptica</i>	65.43	17.20	2.34	41.32	5.08	37.48
<i>K. glauca</i>	68.59	15.88	1.53	40.73	4.95	36.37
<i>M. hypoleuca</i>	65.15	16.96	2.35	42.71	4.83	52.44
<i>L. gracilis</i>	70.48	16.82	1.21	44.32	5.98	49.62
<i>H. brasiliensis</i>	73.77	15.36	0.88	42.12	6.10	51.50
<i>F. uncinata</i>	68.65	19.42	3.13	43.56	5.60	50.71

forest and also its high energy content. Linked with the idea to utilize the potential biomass wisely, we consider that utilization of woody biomass as energy feedstock will be an appropriate way to minimize the negative effects of burning of coal and other fossil fuels due its CO₂ emission. We believe that this idea could be suitable application for development of green energy production combined with green forest-agricultural system to maintain the green environment in harmony with the local wisdom that practically implemented by local people in the forest area.

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