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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 Lamiacea, *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 CO_2 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 investigate 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 (Wiryono *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 tomantosa, Bridelia glauca* Blume,*Callicarpa longifolia* Lam., *Canarium denticulatum, Cratoxylum sumatranum* (Jack) Blume, *Cratoxylum formosum* (Jacq.) Benth. and Hook.f. ex Dyer, *Croton argyratus* Blume, *Cyathocalyx* sp., *Dacryodes* sp., *Dipterocarpusborneensis* Slooten, *Duabangagrandiflora* (DC.) Walp., *Dyeracostulata* (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, *Kleinhoviahospita* L., *Knema glauca* (Blume) Petermann, *Koompassiamalaccensis* Benth., *Leucaena leucocephala, Lithocarpusgracilis* (Korth.) Soepadmo, *Litseaelliptica* 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., *Melicopehookeri* 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* (Laminaceae) 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 midle diversity level. The results also showed that Euphorbiaceae was found as the other 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).

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

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
Vitex pinnata	Lamiaceae	Temaa	4.4	5.94	22.4	32.72
Neonauclea gigantea	Rubiaceae	Tembalut	3.6	2.97	7.0	13.59
Macaranga pearsonii	Euphorbiaceae	Benuaq	2.5	4.95	5.7	13.15
Macaranga triloba	Euphorbiaceae	Benuaq putih	4.7	3.96	3.9	12.63
Litsea elliptica	Lauraceae	Uampak	7.6	1.98	0.9	10.48
Knema glauca	Myristicaceae	Penjalin batu	7.1	1.98	1.3	10.43
Macaranga hypoleuca	Euphorbiaceae	Benuaq putih	3.2	3.96	3.1	10.23
Lithocarpus gracilis	Fagaceae	Palan	5.1	2.97	2.2	10.23
Hevea brasiliensis	Euphorbiaceae	Karet	2.8	2.97	4.4	10.12
Ficus uncinata	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 fited well with the local knowledge and function of woody biomass, whereas those of woody species were traditonally 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 negatively 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})
V. pinnata	21.43	8.57	0.55	18.00
N. gigantean	69.62	15.14	0.48	16.90
M. pearsonii	33.94	11.72	0.26	16.58
M. triloba	33.85	10.33	0.36	17.11
L. elliptica	61.64	12.73	0.37	16.30
K. glauca	48.11	10.06	0.53	16.26
M. hypoleuca	44.73	10.39	0.27	16.14
L. gracilis	21.74	11.14	0.68	16.93
H. brasiliensis	39.80	9.16	0.61	16.93
F. uncinata	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
V. pinnata	71.67	19.32	1.04	43.29	5.86	50.725
N. gigantea	69.59	14.49	0.79	45.34	5.19	37.53
M. pearsonii	69.49	16.30	2.60	43.88	5.69	50.41
M. triloba	71.07	17.08	1.14	44.85	5.87	49.22
L. elliptica	65.43	17.20	2.34	41.32	5.08	37.48
K. glauca	68.59	15.88	1.53	40.73	4.95	36.37
M. hypoleuca	65.15	16.96	2.35	42.71	4.83	52.44
L. gracilis	70.48	16.82	1.21	44.32	5.98	49.62
H. brasiliensis	73.77	15.36	0.88	42.12	6.10	51.50
F. uncinata	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 CO_2 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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References

Amirta, R., Yuliansyah, Angi, E.M., Ananto, B.R., Setiyono, B., Haqiqi, M.T., Septiana, H.A., Londong, M. and Oktavianto, R.N. 2016a. Plant diversity and energy potency of community forest in East Kalimantan, Indonesia: Searching for fast growing wood species for energy production. *Nusantara Biosci*. 8 (1): 22-31. https://doi.org/10.13057/nusbiosci/n080106

Amirta, R., Nafitri, S.I., Wulandari, R., Yuliansyah, Suwinarti, W., Candra, K.P. and Watanabe, T. 2016b. Comparative characterization of Macaranga species collected from secondary forests in East Kalimantan for biorefinery of unutilized fast growing wood. *Biodiversitas*. 17 (1): 116-123. https://doi.org/10.13057/biodiv/ d170117

Amirta, R., Haqiqi, M.T., Saparwadi, Septia, E., Mujiasih, D., Setiawan, K.A., Sekedang, M.A., Yuliansyah, Wijaya, A., Setiyono, B. and Suwinarti, W. 2019. Searching for potential wood biomass for green energy feedstock: A study in tropical swamp-peat forest of Kutai Kertanegara, Indonesia. *Biodiversitas*. 20 (6): 1516-1523. https://doi.org/10.13057/biodiv/d200605

Arung, E.T., Pasedan, W.F., Kusuma, I.W., Hendra, M. and Supriadi, M.B. 2017. Short Communication: Selected medicinal plants in East and North Kalimantan (Indonesia) against Propionibacterium acnes. *Biodiversitas*. 18(1) : 321-325. https:// doi.org/10.13057/biodiv/d180142

Arung, E.T., Amirta, R., Zhu, Q., Amen, Y. and Shimizu, K. 2018. Effect of wood, bark and leaf extracts of Macaranga trees on cytotoxic activity in some cancer and normal cell lines.*J Indian Acad Wood Sci*. 15 : 115–119. https://doi.org/10.1007/s13196-018-0215-4

Bilandzija, N., Voca. N., Jelcic, B., Jurisic, V., Matin, A., Grubor, M. and Kricka T. 2018. Evaluation of Croatian agricultural solid biomass energy potential. *Renew Sust Energ. Rev*. 93 : 225-230. https://doi.org/10.1016/j.rser.2018.05.040

Crepaldi, C.G., Campos, J.L.A., Albuquerque, U.P. and Sales, M.F. 2016. Richness and ethnobotany of the family Euphorbiaceae in a tropical semiarid landscape of Northeastern Brazil. *S Afr J Bot*. 102 : 157-165. https://doi.org/10.1016/j.sajb.2015.06.010

Dale, S.P. and De Blois, S. 2006. Shorter fallow cycles affect the availability of noncrop plant resources in a shifting cultivation system. *Ecol Soc*. 11(2) : 1-26. https://www.ecologyandsociety.org/vol11/iss2/art2/ (accessed 28.10.20)

García, S.G. and Bacenetti, J. 2019. Exploring the production of bio-energy from wood biomass. Italian case study. *Sci Total Environ*. 647 : 158-168. https://doi.org/10.1016/j.scitotenv.2018.07.295

Goh, M.P.Y., Basri, A.M., Yasin, H., Taha, H. and Ahmad, N. 2017. Ethnobotanical review and pharmacological properties of selected medicinal plants in Brunei Darussalam: *Litsea elliptica*, *Dillenia suffruticosa*, *Dillenia excelsa*, *Aidia racemosa*, *Vitex pinnata* and *Senna alata*. *Asian Pac J Trop Med*. 7(2): 173–180. https://doi.org/10.1016/j.apjtb.2016.11.026

Han, S.H. and Shin, S.J. 2014. Investigation of solid energy potential of wood and bark obtained from four clones of a 2-year old goat willow. *Frontier in Energy Res*. 2 (5): 1-6. https://doi.org/10.3389/fenrg.2014.00005

Haqiqi, M.T, Yuliansyah, Suwinarti, W. and Amirta, R. 2018. Response surface methodology to simplify calculation of wood energy potency from tropical short rotation coppice species. *IOP Conf. Series: Earth and Environmental Science*. 144-012041 : 1-7. https://doi.org/10.1088/1755-1315/144/1/012041

Imang, N., Inoue, M. and Sardjono, M.A. 2008. Tradition and the influence of monitary economy in swidden agriculture among the Kenyah People of East Kalimantan, Indonesia. *Int J Soc For*. 1 (1): 61-82. http://www.ijsf.org/dat/art/vol01/ijsf_vol1_no1_04_imang_indonesia.pdf (accessed 28.10.20)

Ivanova, T., Muntean, A., Havrland, B. and Hutla, P. 2018. Quality assessment of solid biofuel made of sweet sorghum biomass. Contemporary Research Trends in Agricultural Engineering, *BIO Web of Conferences* 10 : 02007. https://doi.org/10.1051/bioconf/20181002007

Kiyono, Y. and Hastaniah. 2005. Patterns of slash-and-burn land use and their effects on forest succession: Swidden-land forests in Borneo. *Bull For For Prod Res Inst*. 4 (4): 259-282.

Kenzo, T., Ichie, T., Hattori, D., Kendawang, J.J., Sakurai, K. and Ninomiya, I. 2010. Changes in above-and belowground biomass in early successional tropical secondary forests after shifting cultivation in Sarawak, Malaysia. *Forest Ecol Manage.* 260 : 875-882. https://doi.org/10.1016/j.foreco.2010.06.006

Kumar, A., Kumar, N., Baredar, P. and Shukla, A. 2015. A review on biomass energy resources, potential, conversion and policy in India. *Renew Sust Energ Rev.* 45: 530-539. https://doi.org/10.1016/j.rser.2015.02.007

McKendry, P. 2002. Energy production from biomass (part 1): overview of biomass. *Bioresource Technol*. 83 : 37-46. https://doi.org/10.1016/S0960-8524(01)00118-3

Parikh, J., Channiwala, S.A. and Ghosal, G.K. 2005. A correlation for calculating HHV from proximate analysis of solid fuels. *Fuel*. 84 (5) : 487-494. https://doi.org/10.1016/j.fuel.2004.10.010

Parikh,J., Channiwala, S.A. and Ghosal, G.K. 2007. A correlation for calculating elemental composition from proximate analysis of biomass materials. *Fuel*. 86 (12): 1710-1719.https://doi.org/10.1016/j.fuel.2006.12.029

Slik, J.W.F., Kessler, P.JA. and Welzen, P.C.V. 2003. Macaranga and Mallotus species (Euphorbiaceae) as indicators for disturbance in the mixed lowland dipterocarp forest of East Kalimantan (Indonesia). *Ecol Indic*. 2 : 311-324. https://doi.org/10.1016/S1470-160X(02)00057-2

Susanto, D., Ruhiyat, D., Sutisna, M. and Amirta, R. 2016. Soil and leaf nutrient status on growth of Macaranga gigantea in secondary forest after shifting cultivation in East Kalimantan, Indonesia. *Biodiversitas*. 17 (2): 409-416. https://doi.org/10.13057/ biodiv/d170202

Virmond, E., De Sena, R.F., Albrecht, W., Althoff, C.A., Moreira, R.F. and Jose, H.J. 2012. Characterisation of agroindustrial solid residues as biofuels and potential application in thermochemical processes. *Waste Manag*. 32 (10) : 1952-1961. https://doi.org/10.1590/S0104-66322013000200001

Wiryono, Puteri, V.N.U.and Senoaji, G. 2016. The diversity of plant species, the types of plant uses and the estimate of carbon stock in agroforestry system in Harapan Makmur Village, Bengkulu, Indonesia. *Biodiversitas*. 17 (1): 249-255. https://doi.org/10.13057/biodiv/d170136

Yuliansyah and Amirta, R. 2016. Physico-chemical properties and energy potency of wood waste biomass from the logging activities to generate electricity in East Kalimantan, Indonesia. *AIP Conference Proceedings*. 1755, 040001: 1-6. https://doi.org/10.1063/1.4958476.