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Short Communication: Diversity of plant species growing during fallow period of shifting cultivation and potential of its biomass for sustainable energy production in Mahakam Ulu, East Kalimantan, Indonesia

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Abstract. *Yuliansyah, Haqiqi MT, Septia E, Mujiasih D, Septiana HA, Setiawan KA, Setiyono B, Angi EM, Saparwadi, Sari NM, Kusuma IW, Rujehan, Suwinarti W, Amirta R. 2019. Short Communication: Diversity of plant species growing during fallow period of shifting cultivation and potential of its biomass for sustainable energy production in Mahakam Ulu, East Kalimantan, Indonesia. Biodiversitas 20: 2236-2242.* Fallow period is a time gap, as long as 15 years, for improving natural soil fertility of land used for traditional shifting cultivation, in the tropical areas commonly used by Dayak People in Borneo Island. During this period, many biomass plant species naturally grow and develop a new forest vegetation community with shrub and medium trees, dominated by fast-growing pioneer species. In this study, we investigated the plant diversity in fallowed shifting cultivation area in Batu Majang Village, Mahakam Ulu District, East Kalimantan Province, followed by analysis of the suitability of wood characteristics for energy production. We classified the study area according to the age of fallow period as: 1-3 years, 4-6 years, 7-9 years and 10-15 years. We found 29 species among which 13 were identified as the top species according to the highest value for important value index. Potential wood biomass production increased from 3.01 m^3 ha^{-1} to 399.62 m^3 ha^{-1}. *V. pinnata* and *M. pearsonii* showed the highest dominance which is present in almost all area based on age classification groups. Wood from *V. pinnata* achieved the highest calorific valueof18.00 MJ kg^{-1} whereas *N. cadamba* and *M. sericea* were in the second and third places with the value of 17.30 MJ kg^{-1} and 17.28 MJ kg^{-1}, respectively. Therefore, *V. pinnata* was an important species among all other species observed because of high adaptability and high energy content. In addition, possible energy production at the end of the fallow period of 15 years was 2.92 GJ ha^{-1}.

Keywords: Biomass, diversity, energy, fallow period, shifting cultivation

INTRODUCTION

As one of the tropical countries which have abundant plant biomass diversity and richness, and predicted future energy crisis, Indonesia has decided to start production of green energy and fuels from renewable sources (Amirta et al. 2016). Biomass is known as a renewable energy source which is considered as almost carbon neutral (Bilandzija et al. 2018). By using biomass combustion, it is possible to achieve reduction of net CO_2 emission per unit of heating value, when compared to coal and natural gas (Eldabbagh et al. 2005). Agricultural crops, plant residues, forest resources and special energy plants are common biomass sources to produce energy (Avcıoglu et al. 2019). The shrub species are also reported as good potential feedstock to provide sustainable energy (Dillen et al. 2013; Ghaley and Porter 2014; Hauk et al. 2014; Haverkamp and Musshoff 2014; Pérez et al. 2014; Krzyzaniak et al. 2015; Niemczyk et al. 2018; Gonzalez-Gonzalez et al. 2017; Amirta et al. 2016a; 2019; Martinez et al. 2019). On the other hand, investigation about unutilized biomass sources such as agricultural waste shows great promise as an alternative to cheap raw material. Agricultural waste was also reported as potential sustainable biomass for energy-electricity generation in some countries in the world (Arranz-pierra et al. 2018; Algieri et al. 2019; Bentsen et al. 2019; Huang et al. 2019; Morato et al. 2019).

Shifting cultivation is a traditional agricultural system in tropical regions, commonly used by local communities, including Dayak People of Borneo Island. To implement this farming system, farmers move to a new area to continue planting activity, leaving the old area after harvesting process, This creates a fallow period, as long as 15 years, to improve natural soil fertility. During this period, many biomass plant species grow in the fallow land and develop a new vegetation community with shrub and medium tree dominated by fast-growing pioneer species. The aim of this study is to investigate the plant diversity that grows during fallow period of shifting cultivation and their wood characteristics as feedstock for energy production.

MATERIALS AND METHODS

Study area

This study was conducted in the post shifting cultivation area of Batu Majang Village, District of Mahakam Ulu, East Kalimantan Province, Indonesia (115º12'17.550" E, 0º33'3.039" N). This village has an area of about 29.377 ha and annual temperature of 22-34ºC, while the daily temperatures fluctuate between 3-4ºC. The mean annual precipitation was 3,417 mm, whereas the highest monthly rainfall was obtained in April and the lowest occurs in August amounted to 242 mm, respectively. This area has also relatively high air humidity ranging between 81.42-87.07%.

Diversity of plant species

Plant diversity found at the post shifting cultivation area of Batu Majang Village was studied by making 12 plots with a size of 20 m x 20 m. The diameter and height of the plant species were also measured. The herbarium specimens of all species were collected and deposited at Laboratory of Dendrology and Forest Ecology, Faculty of Forestry, Mulawarman University, Samarinda, Indonesia for scientific identification of the species. In addition, the importance value index of each plant species found in the research area was calculated using the equation of Mueller-Dombois and Ellenberg as described and reported by Wiryono et al. (2016). The wood samples from species with highest important value index were collected and processed with debarking, chipping, powdering and air-drying process for further analysis.

Measurement of wood physicochemical properties

The physicochemical properties, such as moisture content, ash, volatile matter and fixed carbon of wood biomass collected from the plant species were determined according to the method of American Standart for Testing and Material (ASTM) D 7582-12: To determine the elemental composition (carbon-C, hydrogen-H, and oxygen-O) and the wood calorific value, method proposed by Parikh et al. (2005; 2007) was used.

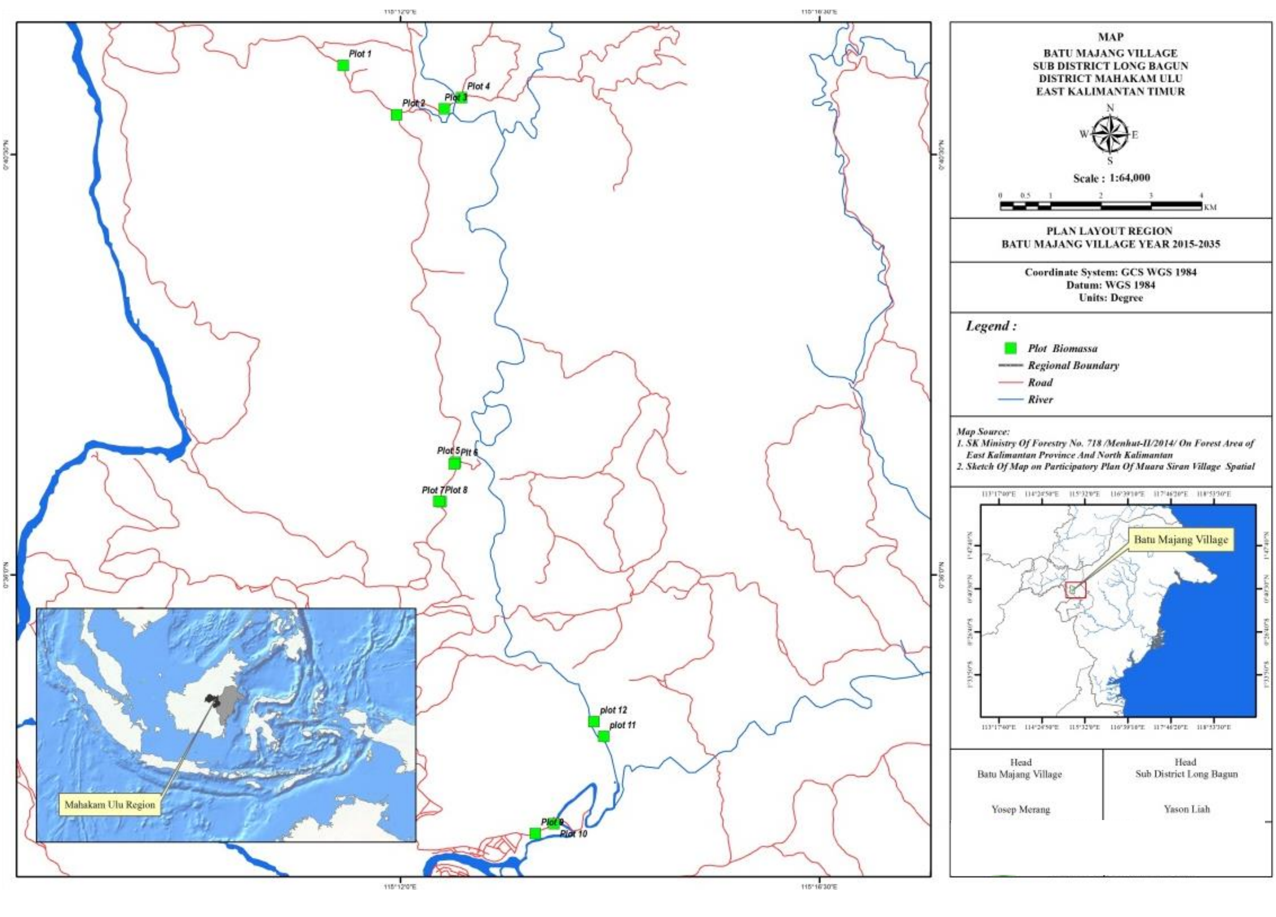

Figure 1. Research locations at Batu Majang Village, Mahakam Ulu, East Kalimantan, Indonesia

RESULTS AND DISCUSSION

Diversity of plant species

Identification of biomass plant species collected from the research plots resulted in 29 species found growing in the community forests during fallow period of shifting cultivation. area. Those plant species were identified as *Antidesma coriaceum* Tul., *Artocarpus elasticus* Reinw. ex Blume, *Bridelia glauca* Blume, *Bridelia tomentosa* Blume, *Callicarpa longifolia* Lam., *Cratoxylum sumatranum* (Jack) Blume, *Croton argyratus* Blume, *Cyathocalyx carinatus (*Ridl.) J.Sinclair, *Dyera costulata* (Miq.) Hook.f., *Ficus aurata* (Miq.) Miq., *Ficus uncinata* (King) Becc., *Glochidion obscurum* (Roxb. ex Willd.) Blume, *Hevea brasiliensis* (Willd. ex A.Juss.) Müll.Arg., *Leucaena leucocephala* (Lam.) de Wit, *Lithocarpus gracilis* (Korth.) Soepadmo, *Macaranga gigantea* (Rchb.f. & Zoll.) Müll.Arg., *Macaranga hypoleuca* (Rchb.f. & Zoll.) Müll.Arg., *Macaranga pearsonii* Merr., *Macaranga triloba* (Thunb.) Müll.Arg., *Madhuca sericea* (Miq.) H.J.Lam, *Melicope hookeri* T.G.Hartley, *Neolamarckia cadamba* (Roxb.) Bosser, *Neonauclea gigantea* (Valeton) Merr., *Piper aduncum* L., *Pterospermum javanicum* Jungh., *Shorea laevis* Ridl., *Syzygium polyanthum* (Wight) Walp., *Trema orientalis* (L.) Blume, and *Vitex pinnata* L (Table 1).

Euphorbiaceae was the dominant family according to the highest importance value index measurements at all levels of age classification in shifting cultivation areas of Batu Majang Village, Mahakam Ulu District. *Macaranga pearsonii* was found with high dominance and was one among the top five species based on IVI, in in age categories of 1-3 years, 4-6 years and 7-9 years. Euphorbiaceae was reported as a pioneer family and its members such as *M. gigantea*, *M. hypoleuca*, *M. pearsonii* and *M. triloba* frequently occupied man places such as rocky outcrops, ruderal environments, disturbed areas, forest and road edges (Crepaldi et al. 2016). 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, and 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 Melastoma and Macaranga were 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 (Amirta et al. 2016b; Susanto et al. 2016; Imang et al. 2008).

Table 1. Plant species collected from the sampling plots located at fallow period of shifting cultivation area in Batu Majang Village

Plant species	Family	Local name	Category	Utilization	Regeneration
Antidesma coriaceum Tul.	Phyllanthaceae	Kayu Abu	Tree	Firewood	Natural
Artocarpus elasticus Reinw. ex Blume	Moraceae	Talun/Taap	Tree	Food, Rope, Firewood	Artificial
Bridelia glauca Blume	Phyllanthaceae	-	Tree	Firewood	Natural
Bridelia tomentosa Blume	Phyllanthaceae	Serapak Lungun	Shrub	Furniture, Firewood	Natural
Callicarpa longifolia Lam.	Lamiaceae	Belebu	Tree	Firewood	Natural
*Cratoxylum sumatranum (*Jack) Blume	Hypericaceae	Duling	Tree	Construction, Firewood	Natural
Croton argyratus Blume	Euphorbiaceae	-	Tree	Firewood	Natural
Cyathocalyx carinatus (Ridl.) J.Sinclair	Annonaceae	Pudu	Tree	Food	Natural
Dyera costulata (Miq.) Hook.f.	Apocynaceae	Jelutung	Tree	Furniture, Firewood	Artificial
Ficus aurata (Miq.) Miq.	Moraceae	Abong	Tree	Firewood, Industrial	Natural
Ficus uncinata (King) Becc.	Moraceae	Abong	Tree	Firewood, Food, Industrial	Natural
Glochidion obscurum (Roxb. ex Willd.) Blume	Phyllanthaceae	Lengidan	Tree	Firewood, Construction	Natural
Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	Karet	Tree	Industrial, Firewood	Artificial
Leucaena leucocephala (Lam) de Wit	Fabaceae	Enep	Tree	Firewood, Food	Artificial
Lithocarpus gracilis (Korth.) Soepadmo	Fagaceae	Palan	Tree	Firewood	Natural
Macaranga gigantea (Rchb.f. & Zoll.) Müll.Arg.	Euphorbiaceae	Jelak Bumbung	Tree	Firewood, Food, Medicine	Natural
Macaranga hypoleuca (Rchb.f. & Zoll.) Müll.Arg.	Euphorbiaceae	Benuaq Putih	Tree	Firewood	Natural
Macaranga pearsonii Merr.	Euphorbiaceae	Benuaq	Tree	Firewood	Natural
Macaranga triloba (Thunb.) Müll.Arg.	Euphorbiaceae	Benuaq Putih	Tree	Firewood	Natural
Madhuca sericea (Miq.) H.J.Lam	Sapotaceae	Sep	Tree	Construction, Food	Natural
Melicope hookeri T.G.Hartley	Rutaceae	Besaii	Tree	Firewood	Natural
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Kayu Tuak	Tree	Construction, Firewood	Natural
Neonauclea gigantea (Valeton) Merr.	Rubiaceae	Tembalut	Tree	Firewood, Food	Natural
Piper aduncum L.	Piperaceae	Kayu Uwa	Shrub	Firewood	Natural
Pterospermum javanicum Jungh.	Malvaceae	Kidau	Tree	Construction, Firewood	Artificial
Shorea laevis Ridl.	Dipterocarpaceae	Abanyit/Awang	Tree	Construction	Natural
Syzygium polyanthum (Wight) Walp.	Myrtaceae	Kayu Uba	Tree	Firewood, Medicine	Natural
Trema orientalis (L.) Blume	Cannabaceae	Karun	Shrub	Firewood	Natural
Vitex pinnata L.	Lamiaceae	Temaa	Shrub	Firewood	Natural

Similarly, *V. pinnata* was also found as a dominant species. Both *M. pearsonii* and *V. pinnata* had high adaptability, especially in the beginning stages of succession to develop new vegetation after harvesting of crop plants. *V. pinnata* was commonly found in the secondary forests of Borneo Island and it is traditionally used by local people as a medicinal plant, especially for treating skin diseases (Kiyono and Hastaniah 2005; Arung et al. 2017; Goh et al. 2017).

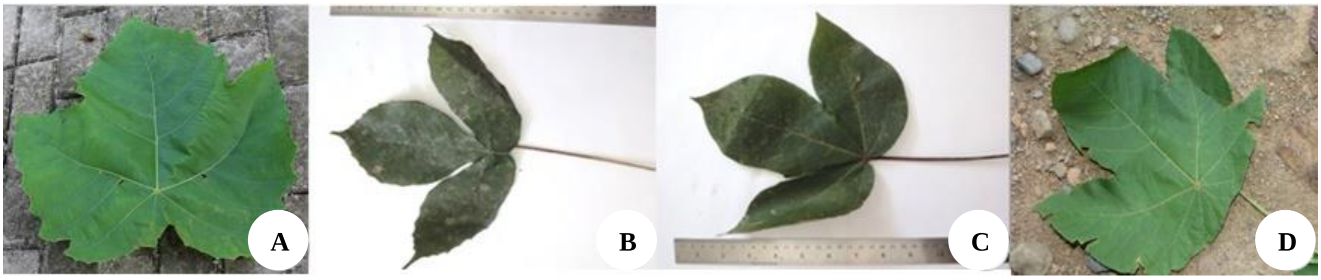

Figure 2. Leave shape of A. *M. gigantea*, B. *M. hypoleuca*, C. *M. Pearsonii*, D. *M. Triloba*

Figure 3. A. Shifting cultivation area, B. *V. pinnata* tree, C. Leaf of *V. pinnata*

Table 2. Top five species having the highest importance value index in different age classification

Age classification	Species	Family	Local name	RDo	RF	RDe	IVI
1-3 years	*V. pinnata*	Lamiaceae	Temaa	12.53	11.11	58.33	81.97
	L. gracilis	Fagaceae	Palan	28.47	11.11	5.00	44.58
	M. pearsonii	Euphorbiaceae	Benuaq	22.44	11.11	10.00	43.55
	F. uncinata	Moraceae	Abong	3.62	11.11	11.67	26.40
	M. hypoleuca	Euphorbiaceae	Benuaq putih	11.38	11.11	1.67	24.16
4-6 years	*N. gigantea*	Rubiaceae	Tembalut	36.85	10.00	33.33	80.18
	F. uncinata	Moraceae	Abong	10.77	20.00	20.00	50.77
	V. pinnata	Lamiaceae	Temaa	19.48	10.00	16.67	46.14
	M. gigantea	Euphorbiaceae	Jelak Bumbung	13.04	10.00	10.00	33.04
	M. pearsonii	Euphorbiaceae	Benuaq	7.82	10.00	6.67	24.49
7-9 years	*V. pinnata*	Lamiaceae	Temaa	44.44	20.00	27.27	91.71
	B. tomantosa	Phyllanthaceae	Serapak Lungun	16.54	6.67	27.27	50.48
	M. gigantea	Euphorbiaceae	Jelak Bumbung	10.78	6.67	9.09	26.54
	M. pearsonii	Euphorbiaceae	Benuaq	4.81	6.67	9.09	20.57
	M. sericea	Sapotaceae	Sep	8.27	6.67	3.03	17.96
10-15 years	*M. triloba*	Euphorbiaceae	Benuaq Putih	24.48	16.67	24.00	65.15
	M. hypoleuca	Euphorbiaceae	Benuaq Putih	20.27	16.67	20.00	56.93
	H. brasiliensis	Euphorbiaceae	Karet	13.66	8.33	20.00	39.60
	N. cadamba	Rubiaceae	Kayu Tuak	11.27	8.33	8.00	30.00
	S. laevis	Dipterocarpaceae	Abanyit	9.35	8.33	4.00	21.68

Table 2. Diameter, height and available wood biomass in different age classification

Age classification	Diameter (cm)	Height (m)	Wood biomass (m^3 ha^{-1})
1-3 years	5.37	6.04	3.01
4-6 years	9.76	10.23	28.97
7-9 years	14.49	10.90	58.30
10-15 years	27.16	22.57	399.62

Wood characteristics of plant species

The results from laboratory analysis showed that physicochemical properties of wood biomass of the species having highest important value index classified by age of the fallow period. Conversion into wood chip successfully reduced the amount of water in wood samples than those of greenwood condition, as shown in table 3. Low moisture content is important for wood to be suitable for solid fuel, for thermochemical conversion into energy (McKendry, 2002). In the present study, *M. pearsonii*, *M. hypoleuca* and *M. triloba* were classified as species with low wood density (<0.4 g/cm^3). The lower wood density is related to fast-growing ability of plant biomass species, thus affecting the cost of transport, storage and drying process (De Oleivera et al. 2013; Amirta et al. 2016a, 2016b, 2019).

Wood biomass from *V. pinnata* showed the highest calorific value (18.00 MJ kg^{-1}). *N. cadamba* and *M. sericea* were in the second and third place with the calorific values of 17.30 MJ kg^{-1} and 17.28 MJ kg^{-1}, respectively. Proximate analysis indicated that the average value of volatile matter was70.29%, fixed carbon was 17.20% and ash content was1.42%, whereas according to ultimate analysis, the average value of carbon was 44.32%, hydrogen was 5.60% and oxygen was 46.77%. Low ash proportion (<5%) is indicative that the wood biomass is suitable to be used as a feedstock for gasifier reactors (Reed and Das, 1998). Composition of volatile matter and fixed carbon also affects high heating value causing flame stability during combustion (Virmond et al. 2012).

Table 3. Physical properties and calorific value of wood biomass species having the highest importance value index

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
L. gracilis	21.74	11.14	0.68	16.93
M. pearsonii	33.94	11.72	0.26	16.58
F. uncinata	60.27	9.40	0.56	15.44
M. hypoleuca	44.73	10.39	0.27	16.14
B. tomantosa	35.64	11.96	0.44	17.06
M. gigantea	41.99	10.46	0.51	16.84
M. sericea	46.22	9.46	0.61	17.28
N. gigantea	69.62	15.14	0.48	16.90
M. triloba	33.85	10.33	0.36	17.11
H. brasiliensis	39.80	9.16	0.61	16.93
N. cadamba	58.54	10.60	0.40	17.30
S. laevis	41.13	10.77	0.48	17.23
Average	42.22	10.70	0.48	16.90

Table 4. Proximate and ultimate analysis of wood biomass species with the highest importance value index

Species	Proximate (%)			Ultimate (%)		
	Volatile matter	Fixed carbon	Ash content	Carbon	Hydrogen	Oxygen
V. pinnata	71.67	19.32	1.04	43.29	5.86	50.73
L. gracilis	70.48	16.82	1.21	44.32	5.98	49.62
M. pearsonii	69.49	16.30	2.60	43.88	5.69	50.41
F. uncinata	68.65	19.42	3.13	43.56	5.60	50.71
M. hypoleuca	65.15	16.96	2.35	42.71	4.83	52.44
B. tomantosa	69.50	17.62	1.18	44.30	5.74	49.86
M. gigantea	68.60	19.40	1.54	43.60	5.44	38.55
M. sericea	72.87	16.69	1.00	47.55	5.01	37.80
N. gigantea	69.59	14.49	0.79	45.34	5.19	37.53
M. triloba	71.07	17.08	1.14	44.85	5.87	49.22
H. brasiliensis	73.77	15.36	0.88	42.12	6.10	51.50
N. cadamba	72.01	16.63	0.77	47.37	5.30	39.33
S. laevis	70.87	17.49	0.87	43.26	6.25	50.30
Average	70.29	17.20	1.42	44.32	5.60	46.77

Biomass productivity from the last cycle of fallow period (10-15 years old) reached an average of 399.62 m^3 ha^{-1} (Table 2). After this period, the vegetation will be cleared and the farmers start new planting activity. The important step in shifting cultivation is burning of some wood biomass residue after fallow period to enhance soil fertility so more nutrition is available for crop plants (Thaler and Anandi 2017). In line with this finding, Fujiki et al. (2017) reported that biomass burning caused flushing of minerals originating from the burnt plant materials. On the other hand, farmers also leave behind some wood biomass at the planting areas which contributes to litter formation and organic matters, to prevent soil from undergoing erosion. In this case, we calculated the average available wood biomass returned for this purpose which was 61.31 m^3 ha^{-1}. Our analysis showed that those wood biomasses contained energy of 2.92 GJ ha^{-1}. Considering this high potency, we also analyzed benefits from the utilization of energy feedstock. First, it can be a new alternative for sustainable heat and electricity for development of remote areas in East Kalimantan province. Second, the waste from energy biomass such as ash can be an alternative to provide mineral nutrients for next agricultural plant on shifting cultivation. We believe that it can be a suitable application towards development of green energy production combined, along with green agricultural system to maintain the green environment.

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