NUSANTARA BIOSCIENCE
Vol. 8, No. 1, pp. 22-31
May 2016

ISSN: 2087-3948
E-ISSN: 2087-3956
DOI: 10.13057/nusbiosci/n080106

Plant diversity and energy potency of community forest in East Kalimantan, Indonesia: Searching for fast growing wood species for energy production

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Manuscript received: 2 January 2016. Revision accepted: 5 March 2016.

Abstract. *Amirta R, Yuliansyah, Angi EM, Ananto BR, Setiyono B, Haqiqi MT, Septiana HA, Lodong M, Oktavianto RN. 2016. Plant diversity and energy potency of community forest in East Kalimantan, Indonesia: Searching for fast growing wood species for energy production. Nusantara Bioscience 8: 22-30.* Nowadays, there is an increasing interest in intensifying the production and use of biomass to replace fossil fuels for the production of heat and electricity, especially for a remote area that generally abundance with the wood biomass resources including in East Kalimantan, Indonesia. In this work, diversity of plant species that commonly growth in community forest area of East Kutai District, East Kalimantan, Indonesia had been studied to point out their energy potency to be used as biomass feedstock for the electricity generated. Diversity of plant species in the community forest was evaluated by making 13 sampling plots with 20mx20m size approximately. Concurrently, the energy properties of plant biomass such as proximate and ultimate compositions were also analyzed using ASTM methods. Results showed that more than 30 species of tropical trees and wood shrubs were grown in the community forest. The presence of them was classified into two different growths of origins: natural and artificial plantation, and also three different categories of plant resources: tree species from logged over forest, commercial fast growing plant tree species for the fiber production and woody shrubs. The highest dominancy and productivity was found in *Paraserianthes falcataria* (L.) Nielsen since the wood biomass was artificially planted for the commercial purposes. Among the 31 plant species analyzed we found the highest energy potency was obtained from *Cratoxylum cochinchinense* (Lour.) Blume that produced 3.17 MWh/ton, and the lowest was from *Trema orientalis* (L.) Blume 0.97 MWh/ton. The woody shrubs species such as *Vernonia amygdalina* Delile., *Piper aduncum* L., *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Calliandra calothyrsus* Meissner., *Bridelia tomentosa* Blume, *Vitex pinnata* L., *Vernonia arborea* Buch.-Ham. and *Bauhinia purpurea* var. *corneri* de Wit. were suitable to be used as sustainable feedstocks for the electricity generated and promising to be developed as energy plant species in the future using Short Rotation Coppice system (SRC).

Keywords: biomass, community forest, electricity, energy plant species, plant diversity

INTRODUCTION

Many developed and developing countries have promoted biomass energy generation through instrumented policies and financial incentives such as feed in tariff schemes to accelerate investment in renewable energy sector (Kumar et al. 2015). As one of the countries which have abundant reserves of forest biomass and agricultural residues and predicted future energy crisis, Indonesia government has also declared to start production of energy and fuels from renewable sources. The government realizes that the bioenergy and biofuels industries will increase the amount of domestic supply of energy and fuels with decrease in subsidy for promotion of the bioenergy and biofuels (Watanabe et al. 2008). 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. Biomass-based energy has several advantages such as wide availability and uniform distribution. Especially, in the remote areas, biomass gasification-based power generation offers a highly viable solution for providing energy demands of small villages and hamlets, which would not only make them independent but would also reduce burden on state electricity boards (Buragohain et al. 2010). In present scenario, global warming, reduction of resources and other international issues has led to the decision of sustainable development, and power sector uses of renewable energy like biomass need them for major green source (Pachauri and Jiang 2008).

East Kalimantan province as a part of Indonesia, has huge amount of forest and agriculture land area. Massive wood biomass and agriculture residues are produced here. This residue contents potential biomass feedstock for energy. However, even though the diversity of plant species and biomass resources are rich, but the lack of information on the basic properties, function and suitability as the feedstock for the energy production, is believed as the main reasons and barrier factors for utilization of the wood biomass.

Recently, much attention has been focused on identifying suitable biomass species, which can provide high-energy outputs, to replace conventional fossil fuel energy sources. Short Rotation Coppice (SRC) or Short Rotation Wood Crops (SRWC) is one option for increasing the supply of wood biomass. Shorter rotation cycles allow higher planting densities and thus, higher biomass yields per unit land area (Dillen et al. 2013; Ghaley and Porter 2014). The biomass increment of SRC/SWRC is high in comparison to that of longer rotation forests (Hauk et al. 2014). The woody shrub plant species such as Willow, Salix, Poplar, Black Locust and also Acacia and Eucalyptus trees were commonly used on SRC system in Denmark, Germany, Poland, Italy, New Zealand and others European countries (Sims et al. 2001; Sims and Venturi 2004; Fiala and Bacenetti 2012; Dillen et al. 2013; Ghaley and Porter 2014; Hauk et al. 2014; Haverkamp and Musshoff 2014; Krzyzaniak et al. 2015).

How about implementation and daily practices of SRC/SRWC in Indonesia? In general speaking, there is no information available for SRC/SRWC and the wood plant species used for the energy-electricity production in Indonesia as far. In Indonesia we only knew and had a conventional concept of the industrial forest plantation for the wood construction and pulp and paper production. Therefore herein this paper, the research was focused on the idea to find out the diversity (plant richness) of fast growing trees and wood shrubs species that potentially used and developed for SRC/SRWC to provide high quality feedstock for the sustainable energy-electricity production in Indonesia, particularly in East Kalimantan, Indonesia.

MATERIALS AND METHODS

Study area

The research was conducted at the community forest located at Telaga Village (116^{o}48’34.656”E, 0^{o}37’7.093” N), Sub district of Batu Ampar, East Kutai District, Indonesia. The community forest at Telaga Village has an area of about 200 ha with annual temperature of 24-30^{o}C, while the daily temperatures fluctuate between 3-4^{o}C. The daily ambient humidity was 80%, 90% in the morning and down to 70% in the afternoon. The annual precipitation was 2367.27 mm, while the mean monthly precipitation ranged between 108.6 mm-322.9 mm (Angi and Ananto 2015).

Sampling procedure

Thirteen sampling plots with the size of 20m x 20m distributed around the community forest of Telaga village, East Kutai were built to collect the data of trees and wood shrubs species richness that potentially used for the energy feedstock.

Forest plant species (wood biomass)

Thirty one samples of tropical plant species consists of tree and wood shrub with diameter about 2-10 cm and their leaves and branches were collected from community forest located at Telaga Village, East Kutai District, East Kalimantan Province, Indonesia. The leaves of plant samples were identified in the Laboratory of Forest Dendrology, Faculty of Forestry, Mulawarman University and recognized as *Acacia mangium* Willd., *Albizia saman* (Jacquin) F. Mueller., *Anthocephalus cadamba* (Roxb.) F. Bosser, *Archidendron clypearia* (Jack) I.C. Nielsen, *Bauhinia purpurea* var. *corneri* de Wit., *Bridelia tomentosa* Blume, *Calliandra calothyrsus* Meissner, *Cratoxylum cochinchinense* (Lour.) Blume, *Fagraea racemosa* Jack ex Wall., *Ficus septica* Burm. F., *Gliricidia sepium* (Jacq.) Kunth ex Walp., *Gmelina arborea* Roxb., *Homalanthus populneus* (Geiseler) Pax., *Hyptis capitata* Jacq., *Licania splendens* (Korth.) Prance, *Macaranga gigantea* (Reichb.f. & Zoll.) Mull.Arg., *Macaranga tanarius* (L.) Mull.Arg, *Madhuca sericea* (Miq.) H.J. Lam, *Melastoma malabathricum* L., *Nauclea officinalis* (Pierre ex Pitard) Merr. & Chun., *Paraserianthes falcataria* (L.) Nielsen, *Piper aduncum* L., *Prunus* sp., *Pternandra azurea* (DC.) Burkill var. *azurea*, *Symplocos fasciculata* (Kuntze) Zoll., *Timonius* sp., *Trema orientalis* (L.) Blume, *Vernonia amygdalina* Delile, *Vernonia arborea* Buch.-Ham., *Vitex pinnata* (L.) Kuntze, and *Vitex trifolia* L. The wood samples were debarked, chipped, air dried, and used throughout this study.

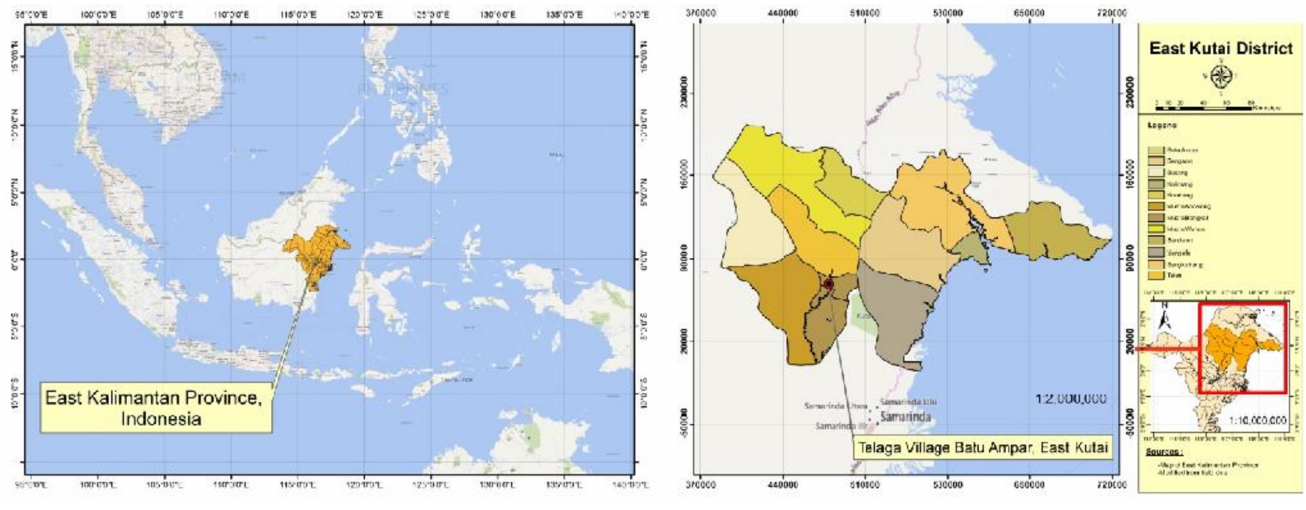

Figure 1. Research location at community forest of Telaga village, East Kutai, East Kalimantan, Indonesia (116^{o}48’34.656”E, 0^{o}37’7.093” N).

Physico-chemical and energy potency analysis of forest plant species

The physico-chemical and energy potency analysis of forest plant species were performed according to the American Society for Testing and Material (ASTM) D 7582-12: moisture content, ash, volatile matter and fixed carbon. In addition, to determine the elemental composition (carbon-C, hydrogen-H, and oxygen-O) and the higher calorific value (HCV), the methodology proposed by Parikh et al. (2005; 2007) was used. The conversion ratio of solid to chip wood form and energy potency was calculated base on the previous report of Francescato et al. (2008).

RESULTS AND DISCUSSION

Diversity of plant species in community forest

Tropical plant species that categorized as tree and shrub (small tree) were observed from 13 sampling plots measured and gave the three groups of plant resources. The first group was the plant species that commonly found and typically growth on the logged over forest area such as *C. cochinchinense*, *Prunus* sp., *L. splendens*, *M. sericea*, *P. azurea* and *A. cadamba*. The plants species were knew and daily used by the people as the wood construction materials due to their growth size, high wood density and also durability. The presence of those plant species were relevance with the history of forest land. Previously, part of the community forest area was a logging concession managed by private logging company and then transferred and owned by the local peoples around there (Angi and Ananto 2015). Most of the woody plant species on this group were grown naturally as well as the condition of secondary forest. Then, the second group was the commercial fast growing wood species such as *P. falcataria*, *A. mangium*, and *G. arborea* that artificially planted by farmers for the fiber production (pulp and paper). In addition, the rest of plants collected were classified as the wood shrubs species such as *F. racemosa, B. tomentosa*, *V. pinnata*, *P. aduncum*, *M. malabathricum* and *T. Orientalis* (Table 1). Currently, those wood shrubs species were not commercially planted and economically benefit for the farmer. The wood shrubs were known as the pioneer plant species that growth sporadically on the gap of forest canopy, degraded land or open area of the community forest (Slik et al. 2003; Goodale et al. 2014). Even they have no economically benefit, but locally and traditionally the wood shrubs species such as *V. amygdalina*, and *M. malabathricum*, were used as herbal drink/tea (from the leaf of plants), local medicine, skin care cosmetic and also fire wood, respectively.

Table 1. Plant species collected from the sampling plots located at community forest of Telaga Village, East Kutai

Plant species		Plant category	Local use	Revegetation
Latin Name	**Local Name**			
Acacia mangium	Akasia	Tree	Pulp and paper	Artificial
Albizia saman	Trembesi	Tree	Fire wood	Artificial
Anthocephalus cadamba	Jabon	Tree	Construction	Natural
Archidendron clypearia	Kelayung	Shrub	-	Natural
Bauhinia purpurea	Kupu-kupu	Shrub	-	Artificial
Bridelia tomentosa	Berduri	Shrub	Fire wood	Natural
Calliandra calothyrsus	Kaliandra	Shrub	Fire wood	Artificial
Cratoxylum cochinchinense	Bengalon	Tree	Construction	Natural
Fagraea racemosa	Kopi-kopian	Shrub	Fire wood	Natural
Ficus septica	Awar awar	Shrub	Fire wood	Natural
Gliricidia sepium	Gamal	Shrub	Fire wood	Artificial
Gmelina arborea	Gmelina	Tree	Pulp and paper	Artificial
Homalanthus populneus	Homalantus	Shrub	Fire wood	Natural
Hyptis capitata	Kayu wangi	Shrub	Herbal tea	Natural
Licania splendens	Kacang	Tree	Construction	Natural
Macaranga gigantea	Serkong	Tree	Fire wood	Natural
Macaranga tanarius	Mahang	Tree	Fire wood	Natural
Madhuca sericea	Telenggawi	Tree	Construction	Natural
Melastoma malabathricum	Karamunting	Shrub	Herbal tea	Natural
Nauclea officinalis	Bengkal	Shrub	Fire wood	Natural
Paraserianthes falcataria	Sengon	Tree	Pulp and paper	Artificial
Piper aduncum	Sirih hutan	Shrub	-	Natural
Prunus sp.	Tembelas	Tree	Construction	Natural
Pternandra azurea	Mutun	Tree	Construction	Natural
Symplocos fasciculata	Simplocos	Shrub	-	Natural
Timonius sp.	Sebulu	Shrub	Fire wood	Natural
Trema orientalis	Kalamboto	Shrub	Fire wood	Natural
Vernonia amygdalina	Sambung nyawa	Shrub	Herbal tea	Artificial
Vernonia arborea	Hamirung	Shrub	Fire wood	Natural
Vitex pinnata	Laban	Shrub	Fire wood	Natural
Vitex trifolia	Vitex	Shrub	Fire wood	Natural

Figure 2. Leave shape variations of plant species collected from the community forest of Telaga Village, East Kutai District, East Kalimantan, Indonesia

Physico-chemical analysis and energy potency of community forest plant species

Physico-chemical and energy potency of community forest plants species were analyzed by evaluating plant moisture content, wood density, proximate, and ultimate compositions and also energy contents. The results in Table 2 showed the average of green/fresh moisture contents (after cutting) and wood densities of forest plant biomass were 51.51% and 0.49 g/cm^3, respectively. The fresh moisture content of wood plant species obtained was very similar with previous results reported for the common SRC plant species (Pérez et al. 2014; Sixto et al. 2015). The results also demonstrated that more than 60% of wood shrubs and 40% of trees species found were classified into middle densities of plant species as expected (Table 2).

In general discussion, we found plant biomass was classified into three different classes of wood density: low, middle and high densities that very related with their growing speed ability and also basic properties and characteristic of each species studied. This phenomenon inline with the previous result reported, biomass physico-chemical properties vary and were commonly associated with plant species and this will greatly affects the utilization of the resource (Vassilev et al. 2010). Therefore, determining various properties such as heating value and chemical components are important (Avelin et al. 2014). From 31 plant species studied we found 7 of them were classified into low density, and 18 species were classified into middle group, while the rest were belonged high density group of woody plant species. The low and middle density of wood biomass (0.3 < 0.4 g/cm^3 and 0.4 < 0.6 g/cm^3) were expected positively correlated with their high speed growth ability, and commonly belongs to pioneer plant species such as *M. gigantea*, *M. tanarius*, *T. orientalis*, and *H. populneus*, (Saranpää 1994; Slik et al. 2003; King et al. 2005). In contrast, the high density (0.6 > 0.9 g/cm^3) of tree biomass such *as C. cochinchinense*, *Prunus* sp., *L. splendens*, *F. racemosa*, *V. trifolia* and *M. sericea* were generally required longer time tro grow and mature. The low density biomass will consumed faster in the reactor (gasifier). The low density of biomass will also causes high transport and storage costs and in many cases it is associated with high humidity that can make it impossible to use (de Oliveira et al. 2013). Thus the use of biomass for energy purposes should be carefully evaluated, analyzing logistical aspects of location, transport, biomass heterogeneity and storage. This is very important since the goal of this study was to explore and find out the fast

Table 2. Moisture content (MC), wood density, and conversion ratio solid wood to wood chip of plant species collected from the community forest of East Kutai District, East Kalimantan, Indonesia

Plant species		Moisture content (green wood) (%)	Moisture content (chip wood) (%)	Wood density (g/cm^3)	Solid-chip ratio (m^3/ton)
Latin name	**Local name**				
A. mangium	Akasia	43.01	9.11	0.64	1.93
A. saman	Trembesi	49.45	14.30	0.33	2.58
A. cadamba	Jabon	58.54	10.60	0.40	2.13
A. clypearia	Kelayung	52.39	12.18	0.49	1.73
B. purpurea	Kupu-kupu	60.89	9.05	0.48	1.77
B. tomentosa	Berduri	42.78	9.11	0.49	1.73
C. calothyrsus	Kaliandra	34.72	10.47	0.49	1.73
C. cochinchinense	Bengalon	40.69	9.06	0.79	1.08
F. racemosa	Kopi-kopian	53.57	9.09	0.64	1.33
F. septica	Awar awar	44.78	10.54	0.34	2.50
G. sepium	Gamal	65.69	7.95	0.53	1.60
G. arborea	Gmelina	51.74	9.77	0.41	2.07
H. populneus	Homalantus	56.24	7.87	0.27	3.15
H. capitata	Kayu wangi	50.45	11.39	0.50	1.70
L. splendens	Kacang	36.85	8.51	0.71	1.20
M. gigantea	Serkong	41.99	10.46	0.51	2.18
M. tanarius	Mahang	57.94	13.31	0.31	2.74
M. sericea	Telenggawi	46.22	9.46	0.61	1.39
M. malabathricum	Karamunting	52.00	10.27	0.55	1.55
N. officinalis	Bengkal	69.62	15.14	0.48	1.77
P. falcataria	Sengon	53.28	9.35	0.31	2.43
P. aduncum	Sirih hutan	62.19	7.73	0.51	1.67
Prunus sp.	Tembelas	40.71	8.51	0.77	1.10
P. azurea	Mutun	50.18	8.32	0.58	1.47
S. fasciculata	Simplocos	64.68	11.18	0.37	2.30
Timonius sp.	Sebulu	65.45	21.93	0.40	2.13
T. orientalis	Kalamboto	49.73	8.23	0.23	3.70
V. amygdalina	Sambung nyawa	50.92	10.23	0.56	1.52
V. arborea	Hamirung	41.64	9.88	0.48	1.77
V. pinnata	Laban	42.01	9.48	0.47	1.81
V. trifolia	Vitex	47.85	13.45	0.62	1.37
	Average	**51.10**	**10.51**	**0.49**	**1.91**

growing trees and wood shrubs species with appropriate physical-chemical and energy properties for electricity production, such as low moisture content (dry matter), middle-high biomass density, high volatile content, high calorific value and also high energy content as well. Moreover, beside the physico-chemical properties the other factors that related with the availability of plant biomass to cover the sustainable needs and supplies of energy feedstock for the operation of power plant annually have been considered by evaluation of their high growth ability, adaptability, and high dry matter productivity of plant species in the community forest or plantation area.

Based on laboratory test and information collected from farmers was showed that the major trees and woody shrubs plant species evaluated were match to these criteria. Fast growing trees species such as *P. falcataria, A. mangium, A. cadamba,* and *G. arborea* were known locally for their very fast growing ability to produced high yield of biomass annually as well as the previous common commercial plant species reported for the fiber and pulp production (Jusoff 2008; Hashim et al. 2015) (Figure 4A). The similar phenomenon was also observed from the wood shrubs plant species showed very fast growing ability and adaptability to be grown in marginal land with high productivity of biomass, whereas the lowest green moisture content (MC) was found from *C. calothyrsus* with the value of 34.72%. Moreover, our results also demonstrated the wood shrub plant species studied was also be able to regrowth naturally as well as SRC/SRWC indicated by generating more than single shoots in their coppice tree. The wood shrubs plant species such as *C. calothyrsus, V. amygdalina, V. arborea, B. purpurea* and *G. sepium* were known growth well and very fast with 5-18 shoots per coppice tree (Figure. 4B). These results obtained were in the same order of magnitude as the results previously reported by Verlinden and co-workers for SRC plant species, poplar. Poplars resprout after coppicing with 5-25 shoots per coppiced tree (Verlinden et al. 2015).

In preliminary analysis of trees and shrubs chip wood, we found after chipping and pre-drying (air drying) processes the average moisture content was relatively low for the chip biomass (10.51%) (Table 2). Chipping and air drying was effectively reduced the moisture content from the wood biomass as much as expected. According to previous report of Brammer and Bridgwater (2002), Pereira et al. (2012) and Pérez et al. (2014) this characteristic

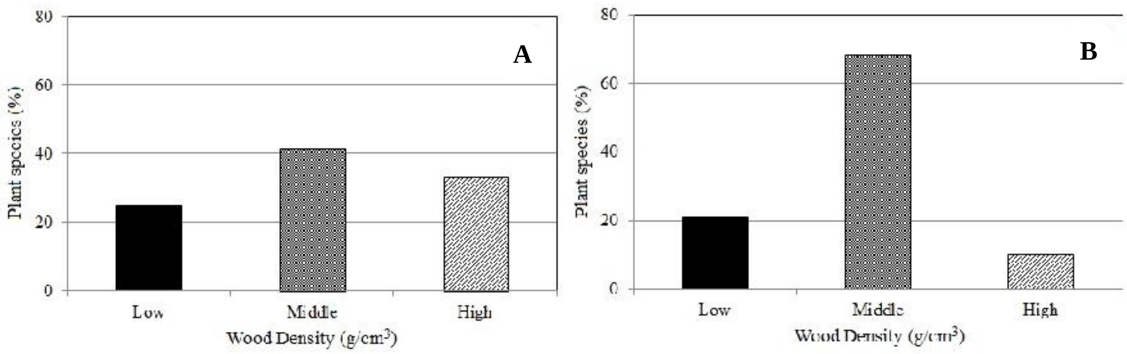

Figure 3. Wood density comparation among trees (A) and wood shrubs plant species (B) collected from the community forest of Telaga Village, East Kutai, Indonesia

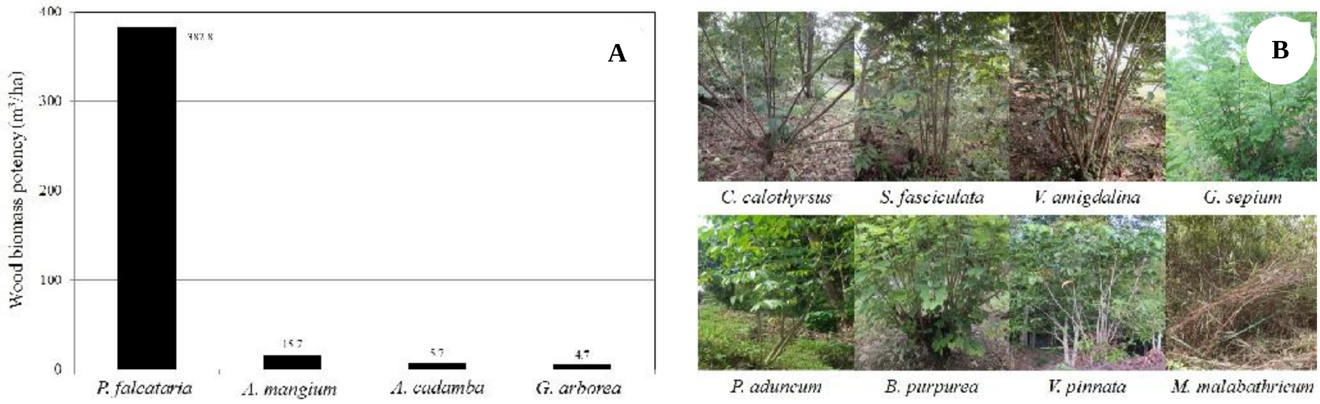

Figure 4. A. Biomass potency from commercial plant species for the fiber production, and B. Wood shrubs plant species collected from the community forest of Telaga Village, East Kutai, Indonesia

favors the use of thermochemical conversion since high moisture content harms the performance of the conversion systems. It is possible to burn any type of biomass but in practice combustion is feasible only for biomass with a moisture content <50%, unless the biomass is pre-dried. The moisture content of the biomass (less than 30%) was suitable for the gasification process. High moisture content biomass is better suited to biological conversion processes instead of the thermochemical conversion processes (McKendry 2002). We also found high proportion of volatile matter from trees and shrubs biomass (70.96%) (Table 3) and these value allows biomass to ignite easily. Volatile matter and fixed carbon was known play an important role on the flame stability during combustion (Virmond et al. 2012).

Furthermore, we found among the twelve trees species studied *C. cochinchinense* exhibit better energy potency indicated by the highest energy production per cubic meter of dry biomass than the others (3.17 MWh/ton) and followed by *Prunus* sp. (3.13 MWh/ton), *L. splendens* (2.92 MWh/ton), *F. racemosa* (2.53 MWh/ton), *P. azurea* (2.43 MWh/ton) and *M. sericea* (2.43 MWh/ton), respectively (Figure 5). Again, the results demonstrated that the high density of wood species (indicated by low value of solid-chip conversion ratio, m^3/ton) will be clearly affect to the high value of energy potency (MWh/ton) (Figure 5). The results obtained were also demonstrated that fast growing trees species, e.g. *G. arborea, A. cadamba, A. mangium* and *P. falcataria* gave lower energy potency than *P. azurea*. The fast growing trees species showed similar potency of energy content per cubic meter of dry biomass (1.37-1.70 MWh/ton). In addition, the woody shrubs species gave better energy potency than fast growing fiber woody species discussed earlier. The results showed that the tropical wood shrub species, *V. amygdalina* gave 2.25 MWh energy potency per ton of dry biomass, followed by *P. aduncum* (2.19 MWh/ton), *M. malabathricum* (2.13 MWh/ton), *G. sepium* (2.08 MWh/ton) and *C. calothyrsus* (2.01 MWh/ton. Those wood shrubs species also showed better volatiles values than the others. The highest volatile content was obtained from *H. populneus* (75.52%) (Table 3). Based on the analysis made on those materials, we suggested that woody biomass were have acceptable heating values and high content of volatiles, carbon, hydrogen, and also oxygen (Table 4). Due to suitable energy properties, growth and also adaptability of those woody biomass, we really believe that plant species can be developed widely to support sustainable supply of biomass feedstock for the green electricity program in this area.

Table 3. Proximate analysis of plant species collected from the community forest of East Kutai District, East Kalimantan, Indonesia

Plant species		Ash content	Volatile matter	Fixed carbon	Calorific value
Latin name	**Local name**	**(%)**	**(%)**	**(%)**	**(kCal/kg)**
A. mangium	Akasia	1.04	72.55	17.30	4263.31
A. saman	Trembesi	1.18	67.64	16.89	3900.90
A. cadamba	Jabon	0.77	72.01	16.63	4150.60
A. clypearia	Kelayung	1.36	68.80	17.67	4135.41
B. purpurea	Kupu-kupu	2.69	70.85	17.41	3920.29
B. tomentosa	Berduri	1.23	72.39	17.27	4112.14
C. calothyrsus	Kaliandra	1.37	68.98	19.18	4205.34
C. cochinchinense	Bengalon	0.55	74.06	16.35	4120.28
F. racemosa	Kopi-kopian	0.79	74.23	15.90	4241.81
F. septica	Awar awar	2.22	69.21	18.04	3961.86
G. sepium	Gamal	4.55	69.57	17.93	4026.77
G. arborea	Gmelina	0.51	71.48	18.26	4282.51
H. populneus	Homalantus	0.52	75.52	16.10	4182.60
H. capitata	Kayu wangi	3.09	68.16	17.37	3537.60
L. splendens	Kacang	0.45	74.03	17.01	4185.40
M. gigantea	Serkong	1.54	68.60	19.40	4039.22
M. tanarius	Mahang	1.09	68.44	17.18	3971.63
M. sericea	Telenggawi	1.00	72.87	16.69	4146.53
M. malabathricum	Karamunting	2.25	70.35	17.13	3798.27
N. officinalis	Bengkal	0.79	69.59	14.49	4055.33
P. falcataria	Sengon	0.52	74.67	15.46	4238.22
P. aduncum	Sirih hutan	1.70	71.29	19.30	4155.74
Prunus sp.	Tembelas	0.43	74.61	16.46	4237.89
P. azurea	Mutun	0.64	73.18	17.87	4275.03
S. fasciculata	Simplocos	3.47	67.83	17.52	3600.30
Timonius sp.	Sebulu	2.28	58.77	17.03	3829.98
T. orientalis	Kalamboto	0.74	72.89	18.12	4186.97
V. amygdalina	Sambung nyawa	1.45	70.29	18.03	4099.56
V. arborea	Hamirung	0.95	71.51	17.66	4105.04
V. pinnata	Laban	0.89	70.96	18.67	4279.75
V. trifolia	Vitex	1.50	67.78	17.28	3830.74
	Average	**0.89**	**70.96**	**18.67**	**4279.75**

Table 4. Ultimate analysis of plants species collected from the community forest of East Kutai District, East Kalimantan, Indonesia

Plant species		Carbon	Hydrogen	Oxygen
Latin name	**Local name**	**(%)**	**(%)**	**(%)**
A. mangium	Akasia	44.01	5.41	39.79
A. saman	Trembesi	45.05	4.94	37.33
A. cadamba	Jabon	47.37	5.30	39.33
A. clypearia	Kelayung	47.05	5.13	38.12
B. purpurea	Kupu-kupu	43.31	5.31	39.02
B. tomentosa	Berduri	47.50	5.27	39.12
C. calothyrsus	Kaliandra	43.65	5.36	38.67
C. cochinchinense	Bengalon	47.51	5.37	40.22
F. racemosa	Kopi-kopian	48.06	5.47	40.17
F. septica	Awar awar	46.25	5.01	38.43
G. sepium	Gamal	43.16	5.2 2	38.57
G. arborea	Gmelina	48.73	5.32	39.33
H. populneus	Homalantus	48.09	5.48	40.84
H. capitata	Kayu wangi	43.23	4.70	37.72
L. splendens	Kacang	48.17	5.39	40.41
M. gigantea	Serkong	43.60	5.44	38.55
M. tanarius	Mahang	45.77	5.01	37.80
M. sericea	Telenggawi	47.55	5.33	39.76
M. malabathricum	Karamunting	42.99	5.32	38.69
N. officinalis	Bengkal	45.34	5.19	37.53
P. falcataria	Sengon	45.51	5.46	40.24
P. aduncum	Sirih hutan	48.40	5.20	39.80
Prunus sp.	Tembelas	48.38	5.47	40.52
P. azurea	Mutun	48.89	5.40	40.26
S. fasciculata	Simplocos	42.05	5.13	37.61
Timonius sp.	Sebulu	42.77	4.53	33.15
T. orientalis	Kalamboto	48.42	5.32	40.20
V. amygdalina	Sambung nyawa	43.54	5.31	38.94
V. arborea	Hamirung	47.44	5.22	39.41
V. pinnata	Laban	48.78	5.29	39.45
V. trifolia	Vitex	44.84	4.89	37.52
	Average	**48.78**	**5.29**	**39.45**

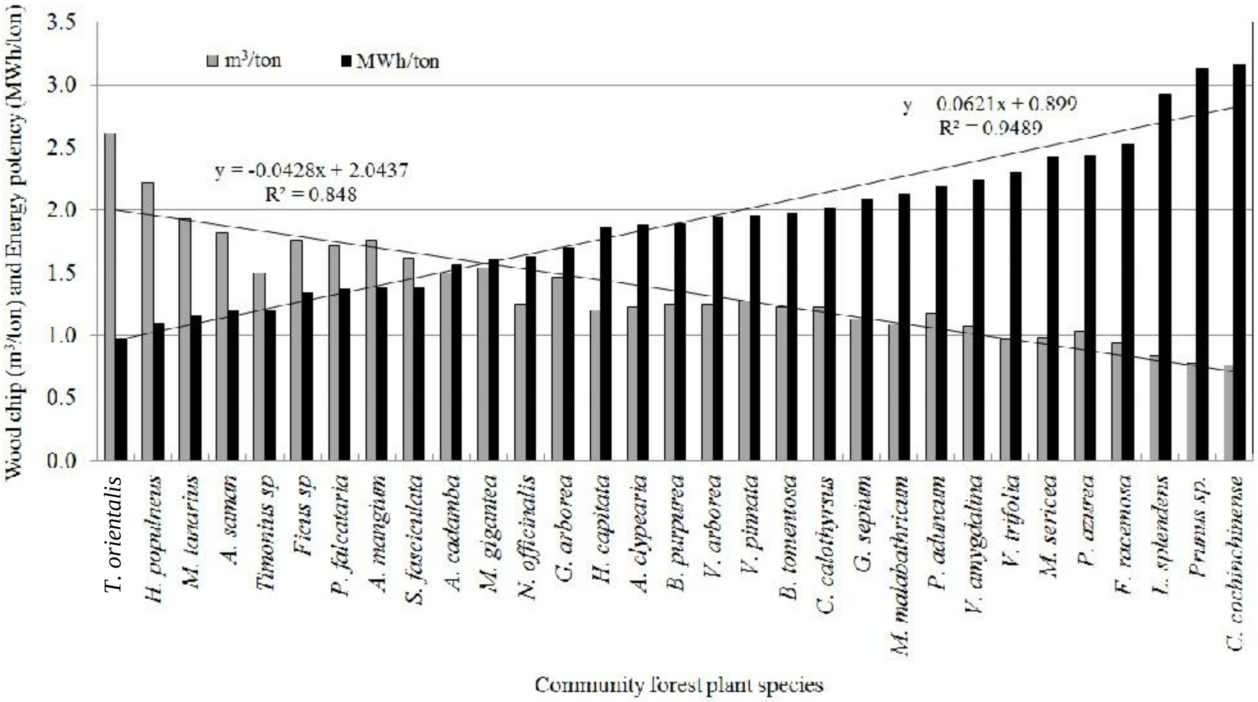

Figure 5. Comparison between wood chip conversion ratio and energy potency from trees and shrubs plant species collected from the community forest of Telaga Village, East Kutai, Indonesia

Finally, our finding suggested that the tropical community forest at Telaga Village, East Kutai, Indonesia has more than 30 plant species richness. The plant species was classified into two different growth of origins: natural and artificial plantation, and also consists of three different categories of plant resources: logged over forest tree species, commercial fast growing plant tree species for the fiber production and wood shrub plant species. Among them we found the wood shrubs plant species such as *V. amygdalina*, *P. aduncum, M. malabathricum*, *G. sepium*, *C. calothyrsus*, *B. tomentosa*, *V. pinnata*, *V. arborea*, and also *B. purpurea* were have the high suitability properties to be used as the energy feedstocks for electricity production purposes such as low moisture content (chip wood), high energy potency per cubic meter of dry biomass and also high volatile content and carbon. These wood shrubs species were also able to regrowth naturally as well as SRC/SRWC plant species indicated by generation more than single shoots on their coppice tree. They were also very promising to be developed and planted widely as energy plant species in the future to provide sustainable energy feedstock and electricity production in this area. This study also gives a new role in the use of wood shrubs and fast growing trees as potential alternative resources for energy feedstocks and sustainable electricity production. The design of the sustainable cycle including development of forest energy plantation using fast growing trees and wood shrubs in the scheme of SRC/SWRC at the community forest area, marginal and degraded lands, and their conversion into energy feedstock will activate the local economy in the tropics with concomitant contribution to the global environment.

ACKNOWLEDGEMENTS

This work was financially supported by the Grant of the Development Planning Agency (BAPPEDA), Government of East Kutai, East Kalimantan, Indonesia through the “Development of Small Scale Biomass Power Plant Project for the Remote Area in East Kutai 2015” (Grant No. 105/B.2/10/2015). We are grateful to Suprihanto and Wahyu Gatut Purboyo from East Kutai Development Planning Agency for valuable discussions on the basic policy of wood biomass utilization for energy and electricity in East Kutai. Special thanks also addressed to Mulawarman University Cleaner Production Clinic (CPCU) for the sharing capacity on this research project.

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