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Potential forest biomass resource as feedstock for bioenergy and its economic value in Indonesia

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ABSTRACT

Indonesia has abundant forest biomass resource, which should not be considered as a low economic value resource. This forest biomass resource can be converted into bioenergy through various technologies and it becomes one of sources in Indonesia's energy mix. This paper focuses on forest residues generated primarily from the harvesting of natural production forests and industrial forest plantations; and wood processing mill residues. The estimated total potential forest biomass in Indonesia for bioenergy in the year 2013 was 132 PJ. About 50.4% resulted from harvesting residues and 49.6% from wood processing residues. Riau province has the largest potential bioenergy followed by Central Kalimantan, East Kalimantan, East Java, South Sumatera, Central Java and Jambi, which all together accounted for 87% of total potential bioenergy. Moreover, three major islands accounted for 95% of total potential bioenergy. Using a conversion return approach, the economic value of forest biomass when it was pelletized was estimated to be about US$ 5.6 per ton wood residues. The economic value of forest biomass is more sensitive to changes in the price of wood pellet than to changes in the collection and hauling cost of wood residues.

1. Introduction

Indonesia's total primary energy supply was about 1.61 billion barrel oil equivalent (BOE) or 9469 PJ for the year 2013 (Ministry of Energy and Mineral Resources of Indonesia, 2015). The largest component of the country's energy mix was crude oil and oil products, followed by coal, traditional biomass (i.e. firewood and charcoal), and natural gas, which together accounted for 93% of the total primary energy supply. Ministry of Energy and Mineral Resources of Indonesia (2015) also reported modern bioenergy supply in the form of biofuels of 4% in the year 2013. The common types of biofuels are bioethanol and biodiesel, which are, respectively, directed as blending substitutes of gasoline and automotive diesel oil for transportation and other industrial engines. The other common type is bio-kerosene, which is directed to substitute kerosene for household and industrial use as well as to generate electricity using low rpm engines in remote areas where the grid extension is not possible.

Indonesia is endowed with abundant forest biomass potential. However, the use of forest biomass for energy is relatively small and restricted to domestic firewood and some small industrial plants. This abundant forest biomass resource should not be considered as a low economic value resource since it can be converted into modern bioenergy through various technologies and become one of important energy sources in Indonesia. FAO (2016) reported that Indonesia produced a modern bioenergy such as wood pellets derived from wood residues, but it was only 40 thousand tons in 2013. About 37 thousand tons of that production were exported mostly to South Korea (94.4%) followed by Japan (2.2%), and European countries (< 1%).

Currently, Indonesia is a net fossil fuel importer. In order to secure the energy supply, save in national import bills and extend the use of modern bioenergy for reducing the fossil oil consumption, the Indonesia government issued the Presidential Regulation No.74/2014 on the National Energy Policy, which set the modern bioenergy share target of 10% in the total primary energy supply by 2025. When the modern bioenergy is derived from forest residues, this energy policy will support the Indonesia government commitment to reduce CO_2 equivalent emission of 41% by 2020 in which the forestry sector is a major contributor (The Indonesia Presidential speech at COP XV

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UNNFCCC in Copenhagen 2009). The reason is that wood energy is almost carbon emission neutral (Schubert and Blasch, 2010; Walker, 2006). Recent findings, however, state that wood energy might emit more carbon in the atmosphere for several years before it gets neutral by biomass regrowth on land (Nepal et al., 2015; Zanchi et al., 2012).

Substantial uncertainties exist regarding the current use and the sustainable future supply of forest biomass feedstock for energy production. Coupled with the sustainable development goal, the economic valuation of the forest biomass is then indispensable to the development of the resource itself and the biomass conversion technology. Several studies on potential forest biomass resources such as forest residues have been conducted at country level, for instances Ackom et al. (2013) for Cameroon, Kemausuor et al. (2014) for Ghana, and (Scarlat et al., 2011) for Romania.

The objectives of this paper are to estimate the availability of Indonesia's forest biomass resource as fuel feedstock, explore its conversion technology for bioenergy and estimate its economic value for a selected conversion technology. The results are intended to foster a better future utilization of forest biomass resource and to inform forest and energy policy developments.

2. Material and methods

2.1. Estimation of forest biomass resource availability for energy

In this study the term "forest biomass resource" refers to all woody biomass generated directly by forest management such as harvesting residues, and wood processing industry such as shavings, sawdust and woodchips. The availability of forest biomass resource for energy was estimated separately for harvesting residues resulting from forest management of natural production forests and industrial forest plantations, and wood processing residues resulting from sawnwood, plywood, veneer sheet, and chipwood mills. Material from early silvicultural thinnings and trees grown in energy plantations were not considered due to the lack of data.

The harvesting residues from either natural production or plantation forests were estimated based on harvest volume produced from those forests. These estimates were calculated by multiplying a merchantable volume of log production with a residual factor and then divided by a recovery rate (or logging productivity). Table 1 shows residual factors and recovery rates that have been measured in several natural production forests (HPH's) and industrial forest plantations (HTI's) as reported in literatures. There were many tree species produced from natural production forests, the so-called mixed tropical hardwood (MTH) i.e. meranti (*Shorea spp.*), kapur (*Dryobalanops spp.*), mersawa (*Anisoptera spp.*), merawan (*Hopea spp.*), keruing (*Dipterocarpus spp.*), benuang (*Octomales spp.*), nyatoh (*Palaquium spp.*), and *Duabanga mollucana,* etc. Meanwhile, tree species produced from industrial forest plantations were among others akasia (*Acacia mangium*), Ekaliptus (*Eucalyptus spp.*), mahoni (*Swietenia macrophylla* and jati (*Tectona grandis*).

As shown in Table 1, the residual factors in natural production forest ranged from 16.8% to 48.1%, with an average of 30.5%, while in industrial forest plantations they ranged from 10.6% to 23.3%, with an average of 16.4%. A residual factor of 30.5% or 16.4% implies a logging productivity of 69.5% or 83.6%. This means that there would be about 0.439 m^3 residues for every 1 m^3 produced log from natural production forest and about 0.197 m^3 residues for every 1 m^3 produced log in industrial forest plantation.

Further, harvesting residues can be distinguished into stumps, short-cut of stems and branches and their shares from total residues were shown in Table 2. On average, short-cut of stems and branches accounted for about 78% to 80% of the total residues.

Harvesting residues are usually left in the forest due to economic reasons (Budiaman, 2001; Nugroho and Oktorio, 2004). They are short and small in diameter and these characteristics are not suitable with forest products industry in Indonesia, which generally processes large diameter logs. In other words, it is costly to utilize harvesting residues with existing forest products technology in Indonesia, except in the recent years when chip wood industry has been developed in Indonesia. Several studies have been conducted to investigate techniques and

Table 1
Residual factors and recover rates in timber harvesting of natural production forest (HPH) and industrial forest plantation (HTI) in Indonesia.

Location/Province	Species[a]	Timber harvesting		References
		RF[b]	RR[c]	
23 HPH in 9 provinces	MTH	23.6%	76.4%	(Simarmata and Sastrodimedjo, 1980)
HPH in South Kalimantan	MTH	20.4%	79.6%	(Sianturi, 1982)
HPH in South Sumatera	MTH	38.0%	62.0%	(Erwinsyah, 1990)
HPH in South Sumatera	MTH	31.2%	68.8%	(Erwinsyah, 1990)
HPH in West Kalimantan	MTH	41.3%	58.7%	(Lim, 1992)
HPH in East Kalimantan	MTH	32.4%	67.6%	(Sukanda, 1995)
HPH in NTB	DM	48.1%	51.9%	(Azwar, 1996)
HPH in Jambi	MTH	39.5%	60.5%	(Budiaman, 2001)
HPH in East Kalimantan	MTH	36.8%	63.2%	(Sasmita, 2003)
HPH in Central Kalimantan	MTH	20.0%	80.0%	(Sari, 2009)
HPH in West Sumatera	MTH	24.6%	75.4%	(Partiani, 2010)
HPH in Papua	MTH	24.8%	75.2%	(Viriandarhenny, 2012)
HPH in Riau	MTH	16.8%	83.2%	(Suwarna et al., 2013)
HPH in Riau	MTH	29.1%	70.9%	(Suwarna et al., 2013)
HPH in East Kalimantan	MTH	31.0%	69.0%	(Larasati, 2013)
HTI in South Kalimantan	AM	17.6%	82.4%	(Hidayat, 2000)
HTI in South Kalimantan	AM	23.3%	76.7%	(Budiaman and Kartika, 2004)
HTI in South Kalimantan	AM	10.6%	89.4%	(Budiaman et al., 2005)
HTI in West Java	SM	16.8%	83.2%	(Budiaman et al., 2005)
HTI in West Java	SM	21.0%	79.0%	(Safitri, 2005)
HTI in East Java	TG	17.8%	82.2%	(Anggoro, 2007)
HTI in East Java	TG	14.5%	85.5%	(Irmawati, 2012)
HTI in East Java	TG	13.6%	86.4%	(Muhtariana, 2013)
HTI in Jambi	AM	12.7%	87.3%	(Aswitama, 2013)

[a] MTH = *Mixed Tropical Hardwood*, DM = *Duabanga mollucana*, AM = *Acacia mangium*, SM = *Swietenia macrophylla*, TG = *Tectona grandis*,
[b] RF = Residual factor.
[c] RR = Recovery rate.

Table 2
Quality of harvesting residues in natural production forest (HPH) and industrial forest plantation (HTI).

Forest types	Timber harvesting residues (%)			References
	Stumps	Short-cut of stems[a]	Branches[b]	
HPH	15.2	45.2	39.6	(Sukanda, 1995)
HPH	37.1	14.5	48.5	(Azwar, 1996)
HPH	16.4	21.4	62.2	(Sari, 2009)
HPH	26.3	29.7	44.1	(Viriandarhenny, 2012)
HPH	18.2	55.4	26.5	(Suwarna et al., 2013)
HPH	8.0	66.2	25.8	(Suwarna et al., 2013)
HPH	19.7	47.0	33.3	(Larasati, 2013)
HTI	22.4	14.7	62.9	(Safitri, 2005)
HTI	22.0	43.6	34.3	(Muhtariana, 2013)

[a] Short cuts of main and upper stems with diameter ≥ 10 cm and length ≤ 40 cm.
[b] Branches with diameter ≥ 10 cm in HPH or branches with diameter ≥ 5 cm in HTI.