# Assessment of the proportion of crop residues subject to open burning available as energy feedstock in Indonesia

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***Abstract***:
*Indonesia is a developing country which economy relies heavily on agricultural production. From such activities a large amount of crop residues are produced each year which could be of potential for energy purposes. Unfortunately, there is an increasing concern over the open burning of biomass resources in the country and notably crop residues that are left unused in the field. Such practices lead to air pollution, human health and economic impacts. This study aimed at investigating farming practices in Indonesia for major crops and estimating the proportion of crop residues unused and subject to open burning that could potentially be available as energy feedstock. One specific location in Indonesia was selected as representative case-study and a field survey using questionnaires conducted. It was found that 21% of Indonesia's crop residues are subject to open burning. On an annual basis, this corresponds to about 45 million tonnes of residues, including, 19.3 million tonnes of rice straw, 18.5 million tonnes of cassava residues, 6.7 million tonnes of corn residues, and 0.4 million tonnes of sugarcane residues. The total energy potential such biomass could represent on a daily basis was estimated to amount to 1706 TJ.*

***Keywords:*** *Crop residues, farming practices, open burning, energy feedstock, Indonesia.*

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## 1. Introduction

Indonesia consists of more than 17,000 islands. The five largest islands are Sumatra, Java, Kalimantan, Sulawesi and Papua. FAO (2015) revealed that 30 % of its land is dedicated to agricultural production. The major food crops produced in the country based on harvested area include, rice, corn, cassava, soybean and peanut. Oanh et al. (2011) indicated that following harvest a proportion of crop residues are used by farmers as composting material, animal feed, roof thatching and fuel for domestic use. However, for a number of reasons including limited access to labor and enhanced access to modern energy, there is an increasing amount of residues remaining unused in the field and subject to open burning. Such a practice has become an issue of growing concern as responsible for a number of adverse impacts including, air pollution, climate change, and health and economic impacts. These are also affecting bilateral relationships with neighboring countries (Permadi and Oanh, 2013; Mahmud, 2013; Gadde et al. 2009). In this study, Indonesia's farming practices for major crops were investigated in order to assess the proportion of crop residues potentially available as energy feedstock as a mean to contribute supporting open burning mitigation.

## 2. Material and Methods

In order to investigate farming practices, since the whole of Indonesia could not be surveyed, the island with the greatest crop production potential was first considered to perform the investigations. Based on crop production data collected from the Indonesian Ministry of Agriculture (2015), Sumatra was identified as the Island with the greatest potential. Following this first assessment, the province in Sumatra with the greatest crop variety and production potential was considered as the case-study location for the field survey. Based on data from the Indonesian Ministry of Agriculture

(2015) the Lampung province was selected. The field survey in Lampung was conducted using a questionnaire to investigate farming practices, including open burning of crop residues. The sampling size $(n)$ for the survey was determined based on the Yamane equation (Yamane, 1967) as follows:

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where 'N' refers to the population of farmers (obtained from the Indonesian Ministry of Agriculture, 2015) and (e) is the desired level of precision, also called sampling error, set at 95%; it represents the range in which the true value of the population is estimated to lie. Based on Eq(1), a sample of 400 farmers was identified to be interviewed which spread over 13 areas in the province.

The questionnaire was designed and developed based on Cheewaphongphan (2010) and was composed of sections including locations of agricultural production sites, types of crops cultivated and farming practices followed by farmers. From this survey, information about the proportion of crop residues burned in the field and proportion used for other purposes were identified.
The data collected from the questionnaire survey was divided into two groups, i.e. crop residues unburned and crop residues burned. Concerning the fraction of crop residues unburned, the information was further sub-dived into 2 groups, namely: crop residues used and crop residues unused. With regard to the utilization of crop residues, 5 main possibilities were identified, including, as animal feeder, fertilizer, fuel, food and others. With regard to the open burning of crop residues, 5 main reasons were identified, including, for soil enrichment in nutrients, pest control, next crop preparation, because of accidents and to eliminate residues.
Based on the data collected from the field survey, the amount of crop residues subject to open burning was estimated for each of the crops investigated. This was done based on the following equation from Street et al., (2003):

$$R = P \times N \times D \times B \quad (2)$$

Where, for a specific crop, R refers to the annual amount of crop residues subject to open burning (tonnes/year); P is the annual amount of crop produced (tonnes/year) at national and/or regional level; N is the Residue-to-Product ratio (also known as RPR), i.e. amount of crop residues produced per amount of product; D is the dry matter-to-crop residue ratio (D); and B is the proportion of crop residues subject to open burning (as identified from the questionnaire survey).

## 3. Results and Discussion

Based on the information collected from the Indonesian Ministry of Agriculture (2015), it was found that rice, corn, cassava and sugarcane are the top four main crops produced in Indonesia and which residues are subject to open burning. Also, it was found that rice is the crop with the largest area harvested, i.e. 12.5 million hectares, followed by corn with 3.3 million hectares, cassava with 0.9 million hectares and sugarcane with 0.4 million hectares.
According to the data obtained from the questionnaire survey and results reported in Table 1, it is observed that more than 80% of rice residues and more than half of all corn residues are unburned and used mainly as fertilizers and animal feeder. For sugarcane, the reverse is observed with over three quarters of its residues being open burned. The remaining fraction is used mainly as fertilizer and animal feeder as is the case for rice and corn. The results obtained for Cassava, which is a perennial woody shrub, are quite different. It is observed that the highest proportion of its residues is unburned (80%) but almost half of that remains unused. This fraction consists mainly of stalk and stubbles. The other half of the unburned residues consists of top and leaves, which are mainly used

as animal feeder (and some other unidentified purposes). Concerning the fraction crop residues open burned, some similarities are also observed for rice, corn and sugarcane with major reasons including soil enrichment, next crop preparation and eliminating residues. For rice and corn as there may be up two to three rounds of production and harvest in a year, open burning is mainly practiced for next crop preparation. For sugarcane, burning of crop residues is practiced in the case of manual harvesting to facilitate harvesting. It is practiced following harvest to enrich soil in nutrients for the next ratoon (there can be 3-5 ratoons); this is the main reason. It is also practiced for the next crop preparation to facilitate planting for a new production cycle. With regard to cassava, farmers mostly eliminate residues via open burning in order to avoid fungal contamination from residues decomposition.

Table 1. Proportion of Crop Residues Burned and Unburned (%)

| Proportion | | Rice | Corn | Cassava | Sugarcane |
|---|---|---|---|---|---|
| Unburned residues | Animal Feeder | 18.79 | 22.78 | 21.53 | 7.64 |
| | Fertiliser | 61.05 | 30.11 | 2.84 | 15.97 |
| | Fuel | 0.53 | 1.39 | 0.05 | - |
| | Food | - | - | 0.36 | - |
| | Others | 1.33 | 1.87 | 19.70 | - |
| | Unused | - | - | 37.54 | - |
| Burned residues | Soil enrichment | 5.74 | 8.82 | 0.81 | 35.25 |
| | Avoid pest | 1.34 | 4.07 | 4.43 | 5.87 |
| | Next crop preparation | 6.68 | 14.53 | 5.77 | 17.63 |
| | Accident | 0.27 | 1.22 | - | - |
| | Eliminate residues | 4.27 | 15.20 | 6.98 | 17.63 |

In table 2, details of the potential of rice, corn, cassava and sugarcane residues as energy feedstock are reported. Based on the proportion of crop residues subject to open burning, sugarcane shows the greatest available potential with 76%, followed by cassava with 56%, corn with 44% and rice with 18%. However, on a dry mass basis, rice straw is observed to provide the greatest potential with 19.3 million tonnes, followed by cassava residues with 18.5 million tonnes, corn residues with 6.7 million tonnes and sugarcane with 0.4 million tonnes. In total, almost 45 million tonnes of these crop residues are burned over year, corresponding to a daily energy potential of about 1706 TJ.

Table 2. Crop Residues Potential as Energy Feedstock

| Crop | $P^a$ ($10^6$ tonnes/year) | $N^b$ | $D^c$ | B (%) | R ($10^6$ tonnes/year) | LHV (MJ/kg) | Energy Potential (TJ/day) |
|---|---|---|---|---|---|---|---|
| Rice | 70.85 | 1.75 | 0.85 | 18 | 19.3 | 11.9 | 628.8 |
| Cassava | 23.44 | 2 | 0.71 | 56 | 18.5 | 15.3 | 774.6 |
| Corn | 19.01 | 2 | 0.4 | 44 | 6.7 | 15.6 | 285.0 |
| Sugarcane | 2.58 | 0.3 | 0.71 | 76 | 0.4 | 15.5 | 17.8 |
| Total | 115.88 | | | | 44.9 | | 1706.2 |

Sources: [a]Ministry of Agriculture of Indonesia (2015); [b]Koopmans and Koppejan (1998); [c]Permadi and Oanh (2013).

## 4. Conclusion

Major crops grown in Indonesia include, rice, corn, cassava and sugarcane. On an annual basis, about 45 million tonnes of these crop residues are open burned. This represents about 21% of the

total amount of crop residues produced nationwide. As an energy feedstock, these residues represent a potential of 1706 TJ/day, with about 45% contributed by cassava, 37% by rice, 17% by corn and 1% by sugarcane.

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