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Estimation of Wood Residues Generation from Sawmilling Activities and Energy Potential in Kwara State, Nigeria

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ABSTRACT

The global concerns about the rise in anthropogenic gases have resulted in alternative clean energy sources. Biomass is one of the most prominent sources of renewable energy, which can be found in wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste (MSW), animal wastes, waste from food processing, aquatic plants and algae. Wood and wood wastes obtained from forest biomass stand at the centre of Renewable Energy Source (RES) due to its availability and usefulness in most developing countries. Sawdust is one of the wood processing residues that are in excess of local demand because of the near absence of its industrial demand in Kwara State. Data relating to its availability, industrial usage and energy potential are rarely available in this study area. This study investigates its availability and inherent energy potential that can be a vital tool for energy policy, planning and development. Wood wastes generated in the state were estimated to be 8012.8 m^3/yr with inherent energy potential of 31298 GJ. By putting sawdust, seen as wastes in most wood processing plants, into efficient use will help reduce the competition for wood as a source of heat for cooking and heating.

INTRODUCTION

The concerns for environmental sustainability through commitments to decreasing greenhouse gas emissions have geared interest in renewable energy sources (RES). Reliance on conventional energy source (fossil fuels) is being threatened due to depletion, price fluctuations and massive contribution to greenhouse gasses. There have been growing interest in bio-energy (energy obtained from biomass) because of its inherent benefits in enhancing rural populace lives through poverty reduction, supply of the energy needs at all times without expensive conversion devices, energy delivery in all forms needed by people (solid, liquid and gaseous fuels, heat and electricity), carbon dioxide (CO_2) neutral and can even act as carbon sinks, and it helps to restore unproductive and degraded lands, increasing biodiversity, soil fertility and water retention (Demirbas et al. 2009). Bio-energy has proven to be an important alternative and more sustainable energy supply. This form of energy can be obtained from living or dead organic matters such as wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste (MSW), animal wastes, waste from food processing, aquatic plants and algae. Wood and wood wastes is the most prominent of bioenergy materials as it accounts for 64%, followed by municipal solid waste (24%), agricultural wastes (5%), and landfill gases (5%) (Demirbas, 2008 and Demirbas et al. 2009).

Wood is used to cook and keep warm for years and it continues to be the largest biomass resource. It can be in solid or processed (pelletized) form for use in residential, institutional, and commercial heating. Waste wood from the forest and lumber processing industry include bark, sawdust, trimmings, planer shavings and board ends (FAO 1993, Thran & Kaltschmitt 2002, Parikka 2004). The size of these wood waste resources depends on how much wood is harvested for lumber, pulp and paper. These waste materials with modern technologies can be processed into useful solid, liquid and gaseous fuels (Vesterines & Alakangas 2001, Sims et al. 2006). These fuels produce very low emissions, generate relatively less acid rain and smog-causing particles, and have a minimal impact on the environment when converted to energy correctly.

Different tropical hardwoods and softwoods species are available to service and sustain the many wood processing industries in the state. Wood-based industrial activities include timber logging, sawmilling, wood-based panel products manufacturing (e.g., plywood, fibreboard and particle board), furniture, pulp and paper making, and matchmaking, wood seasoning and the manufacture of various wooden items such as tool handles, sports goods, weaving equipment and wooden craft. Sawmilling is the process of converting round wood from the forests into lumber by using a variety of machines. Such machines include band mills capable of splitting logs into desired specifications and re-sawing machines for processing the cants and flitches into specified and marketable dimensions (Lucas 1995). Sawdust and other wood wastes are important biomass resources associated with the lumber industry. Enormous quantities of these are generated during log conversion and these depend on factors such as wood properties, type of operation and maintenance of the plants (FAO 1992, Warensjo 1997, Aina 2006). Residues derived from the forest industries can have alternative uses such as chips for pulp production, raw materials for particle board and fibreboard production, or as fuel. The level of utilization is dependent on demand for their use as alternative materials or input for the production of other valuable products.

Wood wastage during log processing has been a major factor responsible for the fast depletion of the state timber resources with its attendant impact on the environment. Minimizing wood wastes during sawmilling process will help reduce the number of trees cut per annum. Wood wastes can be in the form of avoidable and unavoidable wastes (Adekunle et al. 2010). Unavoidable wastes cannot be avoided (prevented) even where the saw kerf is minimal and the mill workers are efficient. Examples of such wastes include sawdust, inconvertible slabs and strips. Avoidable wastes are caused by lack of pre-inspection of trees and logs, inadequate saw maintenance and poor harvesting techniques. These residues left in the forest are in the form of branches, tree crowns, off cuts, twigs, stumps and small diameter sized timbers. Both the avoidable and unavoidable wood wastes generated during harvesting and conversions are enormous and when pooled together can be used in the production of other valuable products such as charcoal, pellet and briquette.

Biomass assessments for energy utilization have been the focus of many researchers in developed economies. These have helped in their energy policy planning and implementation with increased inclusion of bio-energy in their energy supply matrix. Waste materials seen as assets in these developed economies are often disposed off by burning in many developing countries. This further pollutes the environment and creates serious health hazards to human life. The need to address this is the focus of this research, as it aimed to assess the sawdust generated from log processing and inherent energy potential in Kwara State, Nigeria.

MATERIALS AND METHODS

Description of the study area: The study was carried out in Kwara State, located in the North Central area of Nigeria on coordinates 8°30'0" N, 5°0'0"E. The State has a total land area of 36,825 sq.km (14,218.2 sq.mi) and bounded in the north by Niger State, in the south by Oyo, Osun and Ekiti States, in the east by Kogi State and in the west by Benin Republic. There are thirty-two protected forest reserves occupying a total area of 5,792 km^2 (17.82%) of the total land area. The high forest area within the reserves occupies 12.31 km^2 (99.78%). There are only two communal forest reserves in the State, occupying a total land area of about 0.24 km^2. The climate of the State is tropical with distinct wet and dry seasons. The mean annual temperatures vary from 26°C in south to 28°C in north. Annual rainfall is from March to October and varies from less than 750 mm in the north to nearly 1500 mm in the southwest. There are sixty-five sawmills scattered all over the State. The vegetation patterns affect sawmills distribution in the State. The State produces about 9,579 m^3 operating system sawn wood per annum with most of the logs processed in the State.

Data collection and analysis: Information was sourced on the numbers and distribution of sawmills in Kwara State from the Ministry of Forestry and Environment. There are 65 sawmills in the State, 10 were randomly picked to estimate the quantities of sawdust generated during processing. Three working days were allocated to each sawmill investigated with each day comprising of 8 hours of work. Any day with power challenge was continued the next day to make up the 8 hours of work per day. Data on logs processed and sawdust generation were collected from the selected sawmills. Measurement using a 16 ft measuring steel tape was taken of the log height/length, diameters at the base, the middle and the top positions of the logs to be processed. Stem volumes of all lumbers converted were estimated using the Newton's formula (Husch et al. 1982).

$$V_{1=\pi(d_b{}^2+4d_m{}^2+d_t{}^2)}\ {}^{L}\!/_{24} \quad ...(1)$$

Where, V_1 is the volume of log (m^3), L the log length/height (m), and d_b, d_m and d_s are the diameters at the base, middle and top of the log respectively. This expression was used in estimating the volume of each log before processing.

The total volume of the various dimension lumbers obtained per day from timbers in (1) above was obtained using equation 2.

$$V_{1=\pi(d_b{}^2+4d_m{}^2+d_t{}^2)}\ {}^{L}\!/_{24} \quad ...(2)$$

Where, V_2 is the volume of sawn lumbers, m^3; L, B and H are the length, the breadth and the thickness, mm, respectively and n the total number of lumbers gotten. For each 8 hrs working day, the volumes of all lumbers converted were determined and subtracted from those obtained from the log volumes before processing. The difference is the volumes of wood waste as expressed in equation 3. Data collected were analysed using the Microsoft Excel tools to obtain the overall sawdust generated from sawmilling activities in Kwara State.

$$V_w = V_1 - V_2 \quad ...(3)$$

Where, V_w is the volume of waste (m^3), V_1 is volume of round logs before conversion (m^3) and V_2 is volume of lumbers obtained after conversion (m^3).

Energy potential estimation: The energy potential from the generated waste was estimated using an expression given by Edward et al. (2007):

$$PR = IRW \times p \times pr \quad [Gm^3\ year^{-1}] \text{ or } [EJ\ year^{-1}] \quad ...(4)$$

Where, PR is the bio-energy potential of wood processing residues, IRW the consumption of industrial round wood, p is the wood processing residue generation fraction and pr is the wood processing residue recoverability fraction.

Wood processing residue generation fraction (p) is the fraction of consumed wood that is converted into residues during the processing of wood. Different values have been used in many studies (Hall et al. 1993, Heath et al. 1996, Sohngen & Sedjo 2000). The World Resources Institute reported a figure of 0.30 for the best sawmills in Europe and the USA and 0.7 for many developing countries (GFTN/WWF 2000). This study used 0.41 for p based on the ratio of consumed wood and waste generated per day from the study. Wood processing residue recoverability fraction (pr) is the fraction of processing residues that can be realistically collected. Data on the recoverability fraction found in the literature vary considerably; roughly from 0.33 (Hall et al. 1993) to 0.75 (Johanssen et al. 1993, Williams 1995). Yamamoto and co-workers (1999) reported a recoverability fraction of 0.42 for sawmill residues in developing countries and 0.75 in developed countries. This study used a recoverability fraction of wood processing residues of 0.42 because there was no data on the alternative use of the waste generated.

Also, the ultimate analysis for typical biomass materials as given by Clarke et al. (2011) for wood waste is 18.6 MJ/kg.

$$\rho = \frac{M}{V}$$

Mass of wood waste (kg) = $\rho x V$

Where, ρ = Density of wood waste, kg/m^3 (ρ = 210 kg/m^3), V = volume of wood wastes generated, m^3

RESULTS AND DISCUSSION

Sawmills distribution and commonly found wood species in Kwara State: Wood harvesting for sawmilling has been on the increase in the State as the number of wood processing factories have been on the increase. Processed wood consumption has also increased due to urbanization and improvement in the populace standard of living. The sawmills and their distribution in the State are as given in Table 1. The highest number of sawmills was found in Baruten Local Government Area. Most of the sawmills relied on power supply from the National Grid. Some are in clusters at a certain location with single industrial generator to supplement power supply from Power Holding Company of Nigeria (PHCN).

Both hardwood and softwood species were found in sawmills across the State. Table 2 presents the results of some of the common local wood species as observed from the investigation.

Wood conversion and waste generation: The average number of round logs converted per day in each of the sampled sawmills ranges from 18-28. This is mostly affected by the logs size, operators' efficiency, condition of the bandmills, nature of the logs converted, but most importantly level of power supply per day. The maximum number of round logs converted per day was 28 as recorded in sawmill 6 while the least with 18 logs was observed in sawmill 1.

As seen from Table 3, the mean volume of logs converted in the sawmills ranges from 0.8726 m^3 to 1.1150 m^3. The highest volume of logs converted was recorded in sawmill 3, while the least was from sawmill 10. The mean volume of lumbers produced per day ranges from 0.4581 m^3 to 0.6296 m^3. In all the sampled sawmills, the average volume of lumbers obtained was greater than the volume of waste generated. The output per sawmill was greatly influenced by the power supply per day, the size of logs converted, the condition of the band mills and operators' skill. The mean total volume of wood waste generated from the 10 sampled sawmills was 3.9316 m^3. The total volume of wood wastes that can be generated from the 65 sawmills in the State was estimated at 25.60 m^3 per day. In a year, considering 6 working days per week, 8012.8 m^3/yr of wood wastes will be generated. These can serve as raw materials for production of some other valuable products. But this enormous volume of wood wastes is seen littering the premises of these sawmills in the form of huge piles of sawdust and other wastes. In most cases, these are burnt with the smoke given off during burning causing environmental pollution and health hazards, Fig. 1.

Estimated energy potential from the wood wastes generated: An estimated 9.6251 m^3 volume per day of round wood

Table 1: Sawmills and their distribution in Kwara State, Nigeria.

S/N	Local government areas	No. of Sawmills
1	Ilorin East	1
2	Ilorin West	10
3	Ilorin South	Nil
4	Irepodun	8
5	Kaiama	11
6	Ekiti	7
7	Baruten	14
8	Oke-Ero	Nil
9	Offa/ Oyun	3
10	Edu	Nil
11	Moro	5
12	Isin	1
13	Patigi	4
14	Asa	1
15	Ifelodun	Nil
	Total	**65**

Source: Kwara State Ministry of Forestry and Environment

processed was obtained from the 10 sampled sawmills. This translate to 62.56 m^3 volume of round wood consumed per day in the 65 sawmills in the State. For a 6 working day per week, 19581.28 m^3/yr of round wood was consumed in the State. The energy potential inherent in the wood wastes was estimated to be 31298 GJ. This can be integrated to the national grid to meet the energy need of the State.

CONCLUSIONS AND RECOMMENDATIONS

The study assessed the wood wastes generated from sawmilling activities in Kwara State with inherent potential energy value. From the 65 functional sawmills in the State, 8012.3 m^3/yr of wood wastes can be generated. The energy potential inherent in the wood wastes was estimated to be 31298 GJ. These enormous volumes of wood wastes are seen littering the premises of these sawmills in the form of huge piles of sawdust, slabs and off-cuts. In most cases, these are burnt with the smoke given off during burning causing environmental pollution. Harnessing these as input for other valuable products will help to mitigate environmental pollution caused by indiscriminate burning of sawdust as seen in most of the log processing plants. Therefore, the State has tremendous potential to develop the solid, liquid and gaseous fuels through the application of wood wastes and residues.

Table 2: Some common local wood species in Kwara State, Nigeria

S/N	Local name of wood	Scientific Name (s)
1	Iya	*Danielia oliveri*
2	Apa	*Afzelia* spp.
3	Ara	*Pterocarpus erincious*
4	Ayan	*Distemonanthus benthamianus*
5	Ayin	*Anogeissus leoccarpus*
6	Apado	*Berlinia* spp.
7	Igbaa	*Prosopis africana*
8	Mahogany	*Khaya* spp.
9	Iroko	*Milicia excelsa*
10	Teak	*Tectona grandis*
11	Ahun	*Alstonia congensis*
12	Oro	*Antiaris africana*
13	Aye	*Sterculia rhinopetela*
14	Araba	*Bombax* spp.
15	Idigbo	*Terminalia ivorensis*
16	Sapele	*Entandophragma cylindricum*
17	Opepe	*Nauclea diderrichii*
18	Ayinre	*Albizia lebbek*
19	Oriri	*Vitex idoniana*
20	Oro	*Antiaris africana*

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Table 3: Mean volume of logs converted, lumbers produced and waste generated.

Sawmill	Mean of logs converted/day	Mean of volume of of logs converted/ day (m^3)	Mean number of lumbers produced/ day (m^3)	Mean volume of lumbers produced/ day (m^3)	Mean wood waste generated/ day (m^3)
SM1	18	0.9142	310	0.4581	0.4561
SM2	19	0.9716	406	0.5484	0.4232
SM3	23	1.1150	541	0.6296	0.4855
SM4	22	1.0218	478	0.5469	0.4748
SM5	22	1.0146	472	0.6065	0.4081
SM6	28	0.9303	610	0.5835	0.3468
SM7	26	0.8779	488	0.5445	0.3333
SM8	25	0.8846	543	0.6230	0.2616
SM9	19	1.0225	422	0.5646	0.4580
SM10	20	0.8726	451	0.6043	0.2683
Total	223	9.6251	4721	5.6935	3.9316

Fig. 1: Disposal of sawdust by burning.

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