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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 renewable energy sources, which can be found in wood and wood wastes, agricultural crops and their waste byproducts, municipal solid waste (MSW), animal wastes, food processing, aquatic plants and algae. Wood and by-products 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 is 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 their energy requirements with less expensive conversion techniques, energy delivery in all kinds needed by people (solid, liquid and gaseous fuels, heat and electricity), carbon dioxide (CO_2) neutral and can even act as carbon absorbers, and it assists to restore infertile and degraded lands, increasing biodiversity, soil fertility and water retention (Demirbas et al. 2009). Bio-energy has proven to be a vital substitute, and more sustainable energy supply. This energy type can be acquired from living or dead organic matters such as wood and by-products, 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 bio-energy 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 utilization in domestic, institutional, and commercial heating. Wood waste from the forest and lumber processing industry include bark, sawdust, trimmings, planer shavings and board ends (FAO 1993, Thran & Kaltschmitt 2002, Parikka 2004). The volume of these wood waste resources depends on the quantity of wood cut 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 minimal emissions, generate relatively less acid rain and smog producing elements, and have an insignificant effect on the environment when converted to energy correctly.

Different tropical hardwoods and softwoods species are available in the state to service and sustain the many wood processing factories. 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 several wooden items and crafts. Sawmilling is the practice of splitting round wood from the forests into lumber by using a range of machines, such as 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 key biomass resources connected with the lumber industry. Enormous quantities of these are generated during log processing and these depend on factors such as wood properties, operation type and maintenance of the plants (FAO 1992, Warensjo 1997, Aina 2006). Waste obtained from the forest industries can have other uses such as chips for pulp production, raw materials for particle board and fibreboard production, or as fuel. The level of usage 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 fell in a year. Wood wastes can be in the form of avoidable and unavoidable wastes (Adekunle et al. 2010). Unavoidable wastes cannot be prevented even where the saw kerf is marginal and the mill labourers are proficient. Sawdust, inconvertible slabs, and strips are examples of such wastes. Avoidable wastes are caused by lack of pre-inspection of trees and logs, inadequate saw maintenance and poor harvesting methods. 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 huge and when combined together can be utilized 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 undertaken 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%). The state has two communal forest reserves expanding a landmass area of about 0.24 km^2. The climate of the State is tropical having distinct wet and dry seasons. The mean annual temperatures fluctuate 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 almost 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 year 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 quantity of the numerous 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 quantity 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 quantities of all lumbers splitted were calculated and deducted from those obtained from the log volumes before per 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.

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

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):

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

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 wood consumed that is converted into residues during the processing of wood. Different values have been used in many investigations (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 investigation 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 wastes that can be realistically harvested. Data on the recoverability fraction found in the literature differ considerably; roughly from 0.33 (Hall et al. 1993) to 0.75 (Johanssen et al. 1993, Williams 1995). Yamamoto and co-workers (1999) gave a recoverability fraction of 0.42 and 0.75 for sawmill residues in developing and developed countries respectively. This study utilized a recoverability fraction of 0.42 for wood processing residues 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 mean value of round logs converted per day in each of the investigated sawmills ranges from 18-28. The logs size, operators' efficiency, condition of the bandmills, nature of the logs converted and most importantly level of power supply per day influences the logs processed per day. The highest number of round logs converted per day was 28 as obtained in sawmill 6 while the least with 18 logs was observed in sawmill 1.

As seen from Table 3, the mean volume of logs processed in the sawmills ranges from 0.8726 m^3 to 1.1150 m^3. The maximum volume of logs converted was found in sawmill 3, while the least was from sawmill 10. The mean volume of lumbers generated per day ranges from 0.4581 m^3 to 0.6296 m^3. In all the sampled sawmills, the mean volume of lumbers gotten was higher than the quantity of waste produced. The output per sawmill was greatly influenced by the power supply in a day, the logs size converted, the state of the band mills and operators' skill. The mean total volume of wood waste produced 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 these huge quantities of wood wastes are seen spreading around the vicinity of these sawmills in the form of huge heaps of sawdust and other wastes. In most situations these are disposed off through burning causing environmental pollutions and health hazards by the smoky particles discharge (Fig. 1).

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

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

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*

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 scattering at the surrounding of these sawmills in the form of massive lots of sawdust, off-cuts and slabs. In most instances, these are burnt off resulting in 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.

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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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