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# An investigation into some crop residues generation from farming activities and inherent energy potentials in Kwara State, Nigeria

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**Abstract.** In recent time, interest in energy generation from biological materials has been on the increase because of its environmental benefits. The use of these waste materials as feedstock in energy generation plants has been used in many industrial processes. The availability of these wastes is key to the sustainability of such a process. Resource assessment is an important step for planning and implementation of any energy workflow. This research studied the quantity of crop residues generated from farming of some crops in Kwara State and the potential energy contents inherent in them which when properly harnessed can help to alleviate the energy challenge in the state. The crops investigated were rice, maize, sorghum, soybean, and sugar cane. Relevant data were collected by visiting major farm establishments in the state and also the Ministry of Agriculture and Natural Resources (MANR). Obtained production outputs for two farming seasons were analysed using the corresponding residue-to-crop ratios (RPR) to obtain the quantity of wastes generated and the corresponding unit conversion ratio for biomass energy content to obtain the inherent energy potentials. A total crop output of 2531.46 ton was obtained from the study with an estimated residue of 6047.02 tons, and inherent energy potential of 109201 GJ.

**Keywords:** Biomass assessment, bio-energy, residue-to-crop ratios (RPR), waste management, energy potential

## 1. Introduction

The demands for energy over the years have been on the increase due to population growth, economic and technological advancement. The reliance on fossil fuels to meet the energy needs of



humanity is gradually losing popularity because of the associated carbon emissions from its combustion. In order to enhance environmental sustainability, there have been efforts at identifying alternative and renewable sources of energy capable of meeting increasing global demand. The continued existence of living organisms on this planet cannot be sustained indefinitely unless there is a change of attitude and behaviour to the current lifestyle as man constantly keep pushing the boundary of the planet resources to its limit and replacing it with wastes including various emissions [1].

As a safe, reliable and inexpensive energy supply is at the centre of any laudable economic growth and development, access to affordable energy amenities is vital to human activities and wellbeing. Renewable energy derived from biological sources is term bio-energy. These have found applications as a source of heat, electricity, or as a vehicle fuel [2,3]. This is energy confined in living or recently living biological organisms that rule out all forms of fuel products derived from fossil. This form of energy obtained from plant materials is among the most rapidly increasing renewable energy technologies [4]. Organic materials containing bio-energy are biomass. Typical examples of biomass resources are woody biomass and residues, agricultural crops and residues, sewage, industrial residues, animal residues, aquatic plants, landfill gas, and municipal solid waste. Bio-energy is infused in plants through photosynthesis which the animals get by consuming the plants

Issues related to energy security, climate change, modern bio-energy technologies, bio-fuel trade, employment, and local investment have been fundamental in modern economics of energy analysis. Research has shown that no economy in modern age has succeeded at alleviating poverty significantly without effectively increasing the provision, availability, and usage of energy to make material progress [5]. To find a wider acceptance, it is very important to ensure that bio-energy solutions are accessible, affordable and appropriate.

Energy resource assessment is a viable tool for planning and sustainability of any energy-related process as there must be feedstock or input for energy to be generated and made available. Many research efforts have been directed towards estimating the potential of biomass resources at the global level [6,7]. These investigations to estimate agricultural biomass residues and their potential, which examined different results, have been documented in the last 2 decades [4].

For a qualitative appraisal of the sustainability of the current energy usage patterns and the possibility of introducing new biomass fuel-based applications, an evaluation of the available resources for energy has to be done. Hence, this research investigated some crop residues generated from farming activities in Kwara State and their inherent energy potential.

## **2. Methodology**

### *2.1 Description of the Study Area*

This research was undertaken in Kwara State, Nigeria. Kwara state is located in the agro-ecological zone, guinea savannah vegetation of the North Central region of the country. It has four major ethnic groups namely Yoruba, Nupe, Fulani, and Baruba with over 2.37 million populations. The state has sixteen Local Government Area classified into four agricultural zones. It is an agrarian state which has about 260,528 farm families and about 36,820 sqkm hectares of farmland [8,9]. The state shared

boundary in the north with Niger State, in the south with Oyo, Osun and Ekiti States, in the east with Kogi State and a foreign boundary in the west with Benin Republic. The annual rainfall pattern of the state ranges between the months of April and October. It has an average minimum temperature ranging from 21°C-25°C and average maximum temperature from 30°C-35°C [10]. A large percentage of the populace are mainly farmers that specialises in arable crops farming such as maize, melon, groundnut, soybean, sorghum, vegetables, cassava, yam, cowpea, yam, sweet potato, and rice [9]. The climatic and ecological atmosphere is most suitable for the growth of biomass for bio-energy production. The availability of biomass resources follows the same pattern as the state's vegetation. Highest quantity of forest resources are generated in the rain forest of the south while the others are mainly guinea savannah vegetation that generates more of crop residues. Both forest reserves and forest plantations are part of the state's natural endowments.

A huge amount of residues are produced every year from farming activities in the state. These residues constitute a key part of the total annual production of biomass resources and can serve as a significant source of energy both for domestic and industrial purposes. The gross quantity of crop residues generated from agricultural production might not be available in practice due to the fact that some are used as raw materials in non-energy purposes while some are non-recoverable. Quantitative data obtained from the field survey, which was also validated through available information from relevant government agencies were used to quantify and in the conversion of available data to useful energy resources.

### *2.2 Approach to the Study*

Some farm establishments and crop processing sites were visited in Kwara state to assess the biomass generation potentials. Measurements were taken to assess the quantity of agricultural residues that are available which can be utilised for bio-energy planning and production. Data were also sourced from the relevant government ministries which help in the energy potential evaluation of available biomass resources of the state.

The massive available fertile land, favourable climatic and ecological conditions, and agricultural infrastructure of the state have resulted in the generation of enormous biomass. Different cropping systems exist in the state because of the variation in the soil type and vegetation distribution. Residue biomass quantities differ from location to location depending on farming practices and alternative usage of residues. The areas with swampy terrain favour the growth of crops like rice, sugar cane and in the upland are crops such as maize, sorghum, soybean, etc.

For the evaluation of the agricultural residues (biomass) of the state, the annual harvest of the main product was the basis. Hence, the basic data required to perform the evaluation are types of crop, crop output, and plantation densities. Herbaceous crops such as cereals, the grains are the food product harvested, while the remaining parts of the plant are taken as the residues (byproducts) such as the husk, straw, cobs, stover, stalk, bagasse, top/leaves [4].

The biomass residues are generally assessed by the use of residue-to-product ratios (RPR). In the estimation of crop residues quantity, the RPR must be used carefully as they are the key numbers in every evaluation [11,12]. The use of different RPR can have a great effect on the evaluation of

the quantity of byproducts estimated [13]. The RPR used for the crops investigated was presented in Table 1.

**Table 1.** The RPR of the crops Investigated

Crop	Residue Type	Crop to Residue Ratio
Rice	Husk	0.267
	Straw	1.757
Maize	Cobs	0.273
	Stover	2.000
Sorghum	Stalk	1.250
Soybean	Straw	2.500
	Husk	1.000
Sugar Cane	Bagasse	0.300
	Tops/Leaves	0.100

Source: [14-23]

In biomass assessment studies, it is essential to look at the probable present utilization of available crop residues. This is because residues may have a vital economic and soil ameliorating values such as cereal husk and straw used in animal feeding and bedding, staking, mulching, soil moisture management, erosion control, and the manufacturing of compost manure. However, not all of the available resources can be collected due to some techno-economical and environmental factors. Such restrictions stem from preservation of soil fertility, biodiversity conservation, tillage techniques, etc. can limit the amount of harvestable biomass.

Therefore, the resulting calculation techniques adopted in the estimation of the quantity and energetic values or potentials of obtainable crop residues in Kwara State were:

- i. For known amounts of crop production, the quantities of agricultural residues produced were estimated using the residue to product ratio (RPR).
- ii. The energy values of the available crop residues were computed by multiplying the known lower heating values of the plant (MJ/kg) by the estimated mass of the residues.

### 2.3 Bio-energy Potentials Evaluation

The structure of biomass differs considerably among biomass types. The configuration of the biomaterial such as the ash, carbon, hydrogen, nitrogen, sulphur, oxygen and chloride contents are an important elements as it relates to their fuel performance. The energy present in a unit fuel mass (MJ/kg) is measured in term of the heating value of the fuel. The actual energy available for heat transfer in a biomass is the net heating value. The difference in the available energy is explained by the fuel chemical composition, moisture and ash content. For evaluation, the energy content of fuels is reported on a dry basis. The heating values of most agricultural residues are in the range of 14–19 MJ/kg [13,20,22,23].

The ultimate analysis for typical biomass materials based on their dry matter basis (wt.%) is as presented in Table 2. The established heating values were used to evaluate the energy potentials

from a given feedstock of the residues in the state using the unit conversion for biomass energy content in Table 3.

**Table 2.** The Ultimate Analyses for Typical Biomass Materials  
Typical Values

Biomass Type	MJ/Kg	Ash %	Carbon %	Hydrogen %	Nitrogen %	Surphur %	Oxygen %	Chlorine %
Corn Cob	18.00	1.50	48.10	6.00	0.40	0.10	44.00	0.60
Corn Stover	18.20	5.10	43.70	6.10	0.50	0.10	44.60	0.21
Sorghum	17.00	6.60	45.80	5.30	1.00	0.10	42.30	0.24
Rice	18.00	7.70	41.40	5.00	0.70	0.10	39.90	0.34
Straw								
Rice Husk	18.89	18.34	40.96	4.30	0.40	0.02	35.86	0.12
Soybean	18.00	4.30	43.20	6.20	1.80	0.20	44.30	
Bagasses	17.80	9.79	45.00	5.00	0.38	0.01	39.55	0.12
Wood	18.60	1.00	51.60	6.30	0.33	0.10	41.50	0.01
Waste								

Source: [24,25]

**Table 3.** Unit Conversion for Biomass Energy Content

From	To	Multiply by
MJ/kg	BTU/lb	430
BTU/lb	GJ/ton	0.00233

1 MJ/kg = 1 Gigajoule/tonne (GJ/t)

Source: [25]

### 3. Results and Discussion

#### 3.1 Biomass resources quantification and distributions in Kwara State

The study investigated 9 residues from 5 major crops farm in the state. The selected crops were maize, rice, sorghum, soybean, and sugar cane. It must be noted that the quantities of recoverable biomass are usually higher than what is actually available for use because of the other uses of the residues. Crop production has been on the increase for all the residues investigated in the farming season of 2010 and 2011, with 27% for maize, 27% for sorghum, 88% for rice, 6% for soybean and 5% for sugar cane. Agricultural mechanization and government policies were the major drivers of this growth. Hence, increments in these crops output are indicator of an increasing amount of residues that could be derived from them [4].

Analysis of the crops production output of the surveyed Local Government Areas in the state revealed rice farming was predominant in Edu and Patigi Local Government Area (LGA) with other crops like maize, soybean and little plantation of sugar cane basically for human consumption. Edu LGA has the highest crops output because of the presence of The New Nigeria Farmer in Shonga. Maize farming was very prominent in Ekiti, Irepodun, Isin, Oke-Ero, Moro, Ifelodun, Offa and Oyun LGAs. Almost all the estimated crops were found in the different parts of the state but their cropping intensity differs. Sorghum has the least production output because it was not known to be produced on a commercial level. Table 4 give the crop production in the study area, residues types, residues-to-product ratio (PRP) and the estimated residues quantity.

**Table 4.** Survey results for crop production and residues generated.

Crop	Production (Tons)	Residue Type	RPR	Residues (tons)	Qty.
Rice	727.14	Husk	0.27	194.15	
		Straw	1.76	1277.58	
Maize	653.50	Cobs	0.27	178.41	
		Stover	2.00	1307.00	
Sorghum	23.77	Stalk	1.25	29.71	
Soya Bean	843.55	Husk	2.50	2108.88	
		Straw	1.00	843.55	
Sugar Cane	283.5	Bagasse	0.33	93.56	
		Tops/Leaves	0.05	14.18	
<b>Total</b>	<b>2531.46</b>			<b>6047.02</b>	

The total production output was 2531.46 tons with soybean having the highest (843.55 tons) because of the 400 hectares of land cultivated by The New Nigeria Farmer in Edu LGA and sorghum has the least output of 23.77 tons. The estimated residues generated by the various crops were 1471.73, 1485.41, 29.71, 2952.43, and 107.74 tons for rice, maize, sorghum, soybean and sugar cane respectively. The wastes generated in most of the sites surveyed have little or null commercial

demand. They were basically disposed by burning but some have applications as mulching, feeds for livestock, roof thatches, and landfilling.

### 3.2 Feedstocks and their Energy Potentials.

Table 5 present the bio-energy feedstock and estimated energy potential obtained from the study. The results show the estimated feedstock quantity, conversion process, obtainable bio-energy type, and energy potentials values in GJ. The total estimated residue was 6047.02 tons with soybean having the highest. A total of 109201.00 GJ was estimated from the investigation as the bio-energy potential of these energy crops. Depending on the feedstock the biomass residues can be processed through gasification, pyrolysis, fermentation, combustion, anaerobic digestion, briquetting etc. into products like ethanol, methane, methanol, biogas, bio-oil, solid fuel such as briquette, char coal, etc. Based on the level of technology of the study area, briquetting technology will help to produce solid fuel which will assist at offsetting the pressure for wood fuel. The demand for the state forest resources for fire wood and charcoal production will reduce thereby preserving the environment.

**Table 5.** Estimated Feedstock Quantity, Bio-energy Type and Energy Potentials

Feedstock	Qty (Ton)	Conversion Pathway	Bio-energy Type	Estimated Energy Potential (GJ)
<b>Crop Residues</b>				
Rice	1471.74	Gasification; Pyrolysis; Combustion; Briquetting	Biogas; Methane; Methanol; Bio-oil; Solid Fuel	26663.93
Maize	1485.41	Gasification; Pyrolysis; Combustion, Fermentation	Biogas; Bio-oil; Ethanol	26998.78
Sorghum	29.71	Gasification; Pyrolysis; Fermentation	Biogas; Bio-oil; Ethanol	505.07
Soybean	2952.42	Gasification; Pyrolysis; Briquetting	Biogas; Methane; Methanol; Bio-oil; Solid Fuel	53143.74



Sugar Cane	107.74	Combustion; Fermentation; Anaerobic Digestion; Gasification, Briquetting	Methane; Ethanol; Biogas; Bio-oil; Solid Fuel	1889.48
<b>Total</b>	<b>6047.02</b>			<b>109201.00</b>

#### 4. Conclusions

Kwara state biomass resources from crop residues were assessed in this study. It quantified existing biomass residues production from some major agricultural field crops. The results showed that crop residues abound in the state with an overall quantity of 6047.02 tons. Soybean has the highest residues amount (2952.42 tons) while sorghum has the least (29.71 tons). The bio-energy potential of these residues was estimated to be 109201.00 GJ. In spite of the abundant availability of these biomass resources, they are generally not put into effective use. Large quantities are disposed off in the open air by burning. These releases smoky and dust particles into the environment thereby polluting it. Proper bio-energy planning based on the available biomass resources can increase the hopes of the people of the state for an improved and comfortable lifestyle. Briquetting and pyrolysis of these residues will help to meet the energy need of the state populace.

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