FEASIBILITY STUDY OF BIOMASS RESIDUE AVAILABILITY AND BIOFUEL PRODUCTION IN THE GAMBIA

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Abstract – Nowadays, biofuel production has emerged as a suitable alternative means to hydrocarbon. This study assesses the possibility of producing biofuel from agricultural residue in The Gambia. It is also aimed to assess the feasibility of cultivating energy crops for the production of biofuel. The study revealed that there is a huge amount of agricultural residue from the assessment made that can be used as biomass for the production of biofuel and such residues are; groundnut shell waste, rice husks, maize stalks sorghum stalks, cashew shells, and cashew apple waste, etc. These agricultural wastes have the potential to produce biochar and biomass briquettes etc. With the cultivation of energy crops, The Gambia can invest in large plantations of crops such as jatropha which is a good oilseed, sugarcane, etc. The assessment revealed that a very good and comprehensive policy with good strategic plans needs to be installed to get and successfully achieve this goal. More importantly, the collaboration with expert countries in energy crop cultivation and biofuel production areas. In doing these, there will be a good yield with a good quantity of biofuel production as The Gambia have good arable land for cultivation. Some African countries were assessed on their energy crop cultivation and biodiesel and bioethanol production to ascertain that The Gambia can also be involved in such cultivation to produce biofuel.

Keywords: Agricultural Residue, Biofuel, Energy Crop, The Gambia.

1. INTRODUCTION

As the energy demand is on the increase, energy self-sufficiency has become crucial to the socio-economic growth of most emerging countries including The Gambia. The rise in energy demand is due to the rapid socio-economic growth and required great investments and diverse ways to mitigate the demand [1]. The Gambia has been using firewood and charcoals solely for domestic fuel use, which is becoming unsustainable. Thus, there is a great need that a turn to be made towards biomass and biofuel. Most crops such as cereals, fruits, vegetables, and so on are consumed by humans, but forestry residues, crop residues, and fuel woods are extremely valuable [2]. Biomass can be defined as all the renewable organic matters like sea and water plant material, animal products and manure, forestry by-products, food processing, and industrial wastes [3]-[4].

There is enormous potential for contemporary usage of biomass energy in The Gambia. The Gambia has not been involved much in the use of biomass fuel such as briquettes and pellets for domestic use, it has always depended heavily on the traditional or conventional way by the use of firewood and charcoals. The Gambia is an agricultural country and therefore has the capacity of providing a good quantity of agricultural waste for the production of biofuel to be used as a domestic fuel on a larger scale. Global output of biofuels as a renewable energy source continues to increase, and the world is moving toward sustainable bioenergy systems [5]-[6]. The production of bioenergy from biomass residue has a big advantage of zero waste generation [7] and limiting land-use changes as well as land competition for food [8]. Biomass could be a good source of energy in The Gambia because, literature showed that in 2004, Cooking was the greatest energy-intensive used at homes, with firewood accounting for 95 percent of total household energy usage and 2 percent energy usage for charcoal which is the second most used type of domestic fuel [9]. Therefore, biomass can be used as an alternative source of cooking fuel by producing biofuels such as pellets and briquettes from agricultural waste.

This study aims to assess the availability of agricultural waste in The Gambia that has the potential to generate biofuel. In this study, we looked at the possible energy crops that can be cultivated in the Gambia in large areas to produce a good quantity of biofuel. The search also assessed some African countries that are into energy crop cultivation and biodiesel and bioethanol production.

1.1. Agricultural Cultivation in The Gambia

In the economy of the Gambian, agriculture is the most significant sector, it is among the utmost essential sectors for development, especially now that we are in the era of climate change and the global rise of fuel and food.

Agriculture has been the main source of revenue generation in The Gambia employs a workforce of almost 70%. Agriculture is one of the main factors in the growth of the country's gross domestic product (GDP), it contributes almost 25% of the country's GDP [10].

Agricultural farmlands in the Gambia account for almost 54% of the country's total land area [11]. Although agricultural productivity is continuously increasing, Current production levels can only meet approximately 50% of the nation's food needs. The country's crop production is often low, with an average of 1.5 tons/ha, looking at these figures and comparing them to other nations where it is estimated to have a crop yield of 3-4 tons/ha and other countries' yield is up to 6 tons/ha. Groundnut, rice, millet, maize, and sorghum are the primary agricultural crops mainly cultivated. The most common fruits cultivated for cash crops are cashews and mangoes. Rice is the staple crop of The Gambia while cashew and mango serve as the main cash crops. The total arable land for agricultural production is estimated at 558, 000ha, while 320, 000 ha or 57% is put under cultivation annually [12].

1.2. Agroecological Zones (AEZs) of The Gambia

Based on biophysical features, The Gambia has three major agroecological zones (AEZs). The Sahelian zone receives less than 600 mm of total annual rainfall and has up to 70 days of active agricultural production during the rainy season. The Sahelian zone is known for its short period, early maturing, and drought due to its poor water holding capacity soils. The major crops are cassava, cowpea, and sesame, with millet, cultivated relatively infrequently due to the threat of bird damage. The second (AEZ) is the Sudan-Sahelian Zone is highly appropriate for peanuts, sorghum, and cotton in the highland regions. Due to its extended growing season (79 - 119 days) and rainfall isohyets ranging from 600 to 900 mm. The flood plains of the Gambia River and related lowland valley systems, on the other hand, are exceptional rice-growing catchments with tidal swamp irrigation. The Sudanian-Guinean Zone is located along the 900 to 1200 mm rainfall isohyets. The growing season lasts 120-150 days, and in typical seasons, crop water necessities are satisfied throughout the growing season. The main crops grown in this agroecology are early millet, groundnut, rice, maize, vegetable, cowpea, and sesame, (rain-fed upland and lowland, irrigated lowland, mangrove, and mangrove salt-tolerant.

1.3. Food Security Trends

About 46% of rural households were said to be food insecure in 2006., as compared to the 4% in greater Banjul and 15% of the peri-urban. The country's per capita cereal intake was predicted to be 175 kg, with rice accounting for 117 kg and coarse grains such as sorghum maize and millet accounting for 58kg. Food Security Situation and Response Strategies to Food Crisis issues stated that, low, irregular, and unevenly distributed rainfall has severely affected family food security, resulting in poor productivity and production [12]. As a result, rural farmers are forced to sell their products promptly, resulting in revenue loss and a reduction in food reserves.

1.4. Types of Agricultural Residue for Biofuel in The Gambia

Biofuels are described as fuels that are generated from agricultural residue and forest byproducts or the biodegradable component of municipal as well as industrial waste. The primary form of energy in most African countries is biofuel in the form of animal dung and firewood [13]. Agricultural residues and industrial wastes are the major biomass resources in The Gambia. The use of agricultural residue on the farm is significant, and their usage as domestic energy source is expected to face severe competition. Table 1 below shows a projected estimate of the expected available amount of various biomass resources throughout the 2004 - 2008 time period, this was according to a feasibility assessment done in 2004 [9].

Table 1 - Biomass availability projected in 2004 to 2008

Materials (tons)	2004	2005	2006	2007	2008
Millet Stalks	78,500	83,200	88,200	93,500	99,100
Groundnut Shells	19900	21,300	22,800	24,400	26,100
Maize Stalks/Cobs	18,800	20,500	22,300	24,300	26,500
Sorghum Stalks	31,500	34,600	38,100	41,900	46,100
Rice Straws/ Husks	6,900	7,300	7,800	8,300	8,800
Cotton Stalks	1,270	1,300	1,330	1,360	3,400
Total	**156,87**	**168,20**	**180,53**	**193,76**	**210,00**

Table 1 above shows the available biomass in 2004 been projected to 2008. As of today, these figures might have double the quantity if proper data is been kept and new crops and productions been included such as cashew, fonio, etc. The amount of biomass listed in Table 1 above could be a good source for biofuel. These can produce a good quality of biofuel that can be used to salvage the domestic energy issue in The Gambia.

In the present days, biomass utilization in The Gambia is somehow unsustainable and has lots of environmental health problems and it can have contributions to climate change. For a long time now, research has been focused on renewable energy to substitute the common existing traditional energy sources by using biomass energy and agricultural residues [14].

2. CROP PRODUCTION IN THE GAMBIA

2.1. Crop Farming System in The Gambia

In The Gambia, the approximately arable total land area is 38%, or about 430,000 Ha. Groundnuts, rice, millet, and sorghum are the primary agricultural crops cultivated in the country, while rice is the staple crop. Cashew and mango are the most common fruits grown and having groundnut and cashew are the most important cash crops for export. Agricultural output in The Gambia is heavily reliant on rainfall, and the average precipitation has been declining for the previous years. It has a good weather system that is ideal for nearly all production. It has a momentous potential for irrigated agriculture, including freshwater flow from the River Gambia. The sector's overall performance has been uneven, with large and small harvests for good or bad reasons respectively [12]. Table 2 below shows an estimation of a land area farmed with different crops such as coarse grain, paddy (rice) groundnut sesame, and findo between the years 2008 and 2013.

In table 2 shows the total area (hectares) used for

cultivation of the various crop within a range of six years. It showed that the largest area been cultivated is the coarse grain with an average area of 169,363 hectares, and then followed by groundnut with an area of 113,974 hectares, which is one of the main cash crops in The Gambia. Rice which is the staple food for The Gambia account for an area of 48,053 hectares, then having Sesame and findo the lowest respectively.

Table 2 - Cultivated area of main crops Source

Crops	Cultivated Area (Ha)					
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Total Groundnuts	121,843	110,565	122,699	111,924	116,507	100,305
Total Paddy	23,000	32,648	40,671	62,026	63,592	66,380
Total Coarse Grain	157,882	173,804	175,294	165,317	176,199	167,682
Finger millet (Findo)	-	209	429	507	521	491
Sesame	-	1,238	3,303	7,778	7,988	1,582
Total	**302,725**	**318,464**	**342,396**	**347,552**	**364,807**	**336,440**

Table 3 - Main Crop Production Yield

Crops	Production of Major Crops (Mt)					
Year	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Total Groundnuts	108,884	116,420	98,479	86,517	122,542	94,371
Total Coarse Grain	179,831	145,669	146,736	131,722	168,536	157,665
Total Paddy	34,294	49,964	62,926	51,136	54,219	69,704
Total	**323,009**	**312,053**	**308,141**	**269,375**	**345,297**	**227,369**

Table 3 above shows the harvest of three main crops grown in The Gambia, and as per table 2 showed the area that has been cultivated and the production also followed as per the size. In table 3, above we had coarse grain having the highest production yield at an average amount of 155,027 metric tons, groundnut at an average amount of 106,568 metric tons, and paddy the lease with 53,707 metric tons. The values for sesame and findo weren't recorded or found from the source material, and by assumption based on the size, the area cultivated will record a very low yield because many farmers are not into its cultivation.

2.2. Regional Production Yield of Crops Farming

The Gambia is divided into five administrative areas known as West Coast Region, North Bank Region, Central River Region, Lower River Region, and Upper River Region. In the five areas farming differ a little due to the different land profile and also the climate conditions. A study was made to determine the production yield of every region on three basic crops such as rice, groundnut, millet sesame, and findo. Table 4 below shows the average regional production per hectare of the most common crops cultivated within the regions.

Table 4 - Average Regional Crop Production (kg/ha).

Average Crop production per region (kg/ha)							
Regions	**Groundnut**	**Sorghum**	**Rice**	**Millet**	**Maize**	**Findo**	**Sesame**
West Coast Region	1661	1110	2025	2055	1243	873	268
North Bank Region	2042	1120	2435	1739	1040	0	295
Central River Region	3360	1756	3327	3155	1768	0	625
Lower River region	1898	965	1775	2178	933	900	324
Upper River Region	1884	1095	998	1980	990	812	350
Total	**10,845**	**6,046**	**10,560**	**11,107**	**5,974**	**2,585**	**1,862**

Table 4, above shows the average crop yield in the various administrative regions in The Gambia. This is to help determine the quantity of feedstock that is possible to be available for biomass energy production per region.

2.3. Potential use of Biofuel in The Gambia

Biomass is a key source of energy in Africa, more than 90% of the produced wood is utilized to provide the primary energy demands [17]. Another function of biomass in Africa is livestock rearing and therefore pastoralism plays an important function. In underdeveloped nations, The Gambia especially, fuelwood and charcoal are essential sources of energy for homes and small businesses [18]. The current price increases in fossil oil globally, the worries of energy and climate change, which is caused by greenhouse gas emissions, have encouraged countries both developed and underdeveloped to explore biofuels production [19]. Like The Gambia, many sub-Saharan countries consider biofuels as a means to boost rural development, create jobs, etc. The United States is one of the leading producers of ethanol derived from maize and The Gambia on the other hand produces maize in good quantity and is used for cereal food purposes only. A good policy or framework can be developed in partnerships with countries involved in the production of biofuel, and as agriculture has been one of the main activities in The Gambia a good quality of biofuel can be obtained if exploited.

2.3.1. Bioenergy Crops (Woody Energy Crops and Perennial Crops)

In The Gambia, the following energy crops have a good potential of producing feedstock for biofuel production they are maize, cassava for ethanol, sorghum, soybean, cashew nuts, and jatropha for biodiesel.

Maize: as stated earlier on, maize is used to produce ethanol for transportation in the United States. Annually, millions of hectares of land are used to cultivate maize in sub-Saharan Africa. Maize is grown all over The Gambia in large quantities during the rainy seasons and also during the off-season which is irrigated in farmland or gardens.

Cassava: is one of the most important food crops in The Gambia which could be a good source of biofuel. In Ghana, it is a staple crop and there is a good production yield in millions annually [20].

Sorghum: this crop is so vital because of its potential feedstock for the production of bioethanol. Usually, the grains are used as food crops and the waste stalk is utilized as good fodder. Because of its rich sugar content, the stalk is highly regarded as a feedstock for biofuel production. In sub-Saharan Africa, it is recorded that approximately 25 million hectares of land are used for the cultivation of sorghum [19].

Jatropha curcas: is a multifunctional plant with several properties and significant potential. It is a tropical plant that may be cultivated in places with little too high rainfall and can be used to recover lands [21]. Locally the plant is used for fencing gardens and orchards because animals don't eat its fruits and leaves. Jatropha has a short establishing time of 2 to 5 years and a lifespan of up to 50 years. In The Gambia jatropha plantation has just started to be cultivated in recent years, therefore, it is still a young crop within the community although with the potential of biofuel.

Cashew: Cashews is part of the Anacardiaceae family, it is a tropical American native that is extensively available in Asia and Africa, and it is an economically significant agricultural product [22]. Literature shows that for every tonnage of cashew nut produced about ten to fifteen tonnages of cashew apples can be obtained as by-products. [23]. From the reviews made so far, it could be concluded that there is available cashew apple residue that could be used for biofuel production [24]. Bio-briquette has been successfully produced from biochar by-products of the liquid smoke production from cashew nut shells residue [25]. This goes to show how cashew biomass can be used for biofuel.

3. DISCUSSIONS

3.1. Benefits of Biofuels in The Gambia

In The Gambia, plans and innovations are on the pipeline for biofuel production, this is important to reduce rural poverty and the contribution forwards access to affordable and clean energy by the rural Gambia. Electricity access is still not available to all especially those in the upper and remote areas. The Gambia is the smallest country in West Africa, the introduction of biofuel will have a great benefit in helping bosh the energy sector. The establishment of biofuel production will benefit The Gambia enormously in various ways as stated below.

- The development of biofuel factories will help rural people utilize the biofuel for household use etc.
- Biofuel initiatives will help in the energy sector, diversify its fuel alternatives, and decrease the rate of fuel importation.
- Agricultural raw materials (feedstock) can be exported to certain industrialized countries that lack sufficient land for the development of biofuel feed-stocks.
- The development of biofuel businesses would create more job opportunities and enhance the energy sector.
- The commercialization of biofuels technology will help to mitigate carbon emissions to a percentage that can be determined by the amount of biofuel produced from the agricultural waste stated, as the concentration will be on clean energy.

3.2. Initiatives for Biofuels in some African Countries

Use Few African countries are doing well in biofuel production and is helping in their energy sector, reviewing what those countries have done The Gambia can equally product or invest in those areas to as well be a good producer of biofuel. Some of these countries and what they are doing is as follow:

Ghana: they implemented a bioenergy program in 2010, with the goal of replacing 10% of the nation's petroleum fuel with biofuels by 2020 and the same policy should continue to achieve 20% by 2030 and to reduce carbon dioxide emission [26]. This was done in an effect to make good use of the biomass resources available in the country by producing biofuel.

Burkina Faso: Among the African countries this is a country that is seriously affected by the energy crisis [27]. Biofuel expansion initiatives programs are been carried out in recent years in an effort to address this issue. In 2009, the government implemented a program to plant over 70,000 jatropha oil seed trees [28]. This is a very good initiative to combat the energy crisis.

Senegal: next-door neighbors country also invested in biofuel development projects in recent years to improve their energy sector. This was done by the cultivation of hectares of land of jatropha oil seeds and other feedstocks in the regions of Touba and Tamba Counda [29], this was achieved with the aid of experts from biofuel production countries.

Nigeria: there is a rising interest in the development of biofuels. As a result, numerous biofuel and biodiesel production projects have been undertaken, ranging from feasibility studies to the building of refinery plants [28]. As of now, there are five main commercial-scale ethanol plants that generate up to 134 million liters of ethanol per year [30].

Other countries like; Zimbabwe, Sudan, Uganda, and Kenya all launched similar initiatives. Kenya and Sudan have ceased producing ethanol, however, Kenya has subsequently resumed production. Zimbabwe has continued to produce ethanol, although the majority of it is exported as alcohol. The government of Uganda is in charge of promoting the growth of the biofuels industry with policies and good regulations. There are a series of

biofuel initiatives in Mali that is more engaged by the local people in the provision of raw materials [27].

Table 5 below shows the other biofuel development programs that have been going on in some of these African countries.

Table 5 - Biofuel Production from Agricultural Residue

Country	Feedstock	Bioethanol (ML)	Biodiesel yield (ML)
Swaziland	Molasses	480	-
Kenya	Molasses	413	-
Sudan	Molasses	408	-
Tanzania	Molasses	254	-
Malawi	Molasses	146	-
Uganda	Molasses	119	-
Ethiopia	Molasses	80	-
Nigeria	Sugarcane	70	-
Mali	Molasses	20	-
Ivory Coast	Molasses	20	-
Burkina Faso	Sugarcane	20	-
Benin	Cassava	20	-
Senegal	Molasses	15	-
Guinea Bissau	Cashew	10	-
Ghana	Jatropha	-	50
Niger	Jatropha	-	10
Togo	Jatropha	-	10

Table 5 above shows the different types of biofuels produced and the quantity from each country showing the biodiesel and bioethanol. It is clear that Molasses is one of the popular feedstocks for the generation of bioethanol fuel in many African countries, while jatropha oil seeds are commonly used for the production of biodiesel fuel. Cassava, sugarcane, cashew is also other good product for bioethanol.

3.3. The CO2 Emissions in The Gambia

Carbon dioxide emissions can be said to be those that are stemming from the burning of fossil fuels and also from the manufacture of cement. These include carbon dioxide produced during the consumption of liquid, solid, and gas fuel.

The Gambia is one of the world's least polluting nations, however, is it said to be responsible for about 0.05 percent of the world's emissions. More efforts and plans are in place to mitigate this emission through a range of activities, these include agroforestry, planting biofuel plants, and also to improved soil management. Other activities that are been implemented to reduce CO2 emission are the use of solar and wind energy for electrification and reducing transmission power loss. These are all ways to reduce CO2 emissions. In The Gambia, the highest CO2 emission is from the energy sector, with the plans stated above it can reduce the emission rate [31].

However, figure 1 below can show the total CO2 emission for the past ten years showing little increment yearly.

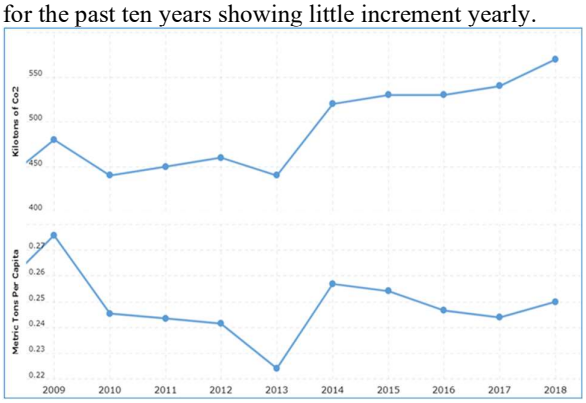

Fig. 1 - The Gambia CO2 Emissions

Figure 1 above shows the yearly increment of the CO2 in The Gambia, the C02 emissions for 2009 was 480, which have increased to 570 in 2018. In 2018, the CO2 emissions per capita for The Gambia was 0.25 metric tons. Though The Gambian CO2 emissions per capita fluctuates substantially in recent years.

4. CONCLUSION

This paper assessed the potential production of biofuel energy to increase the energy demand in The Gambia by using the amount of agricultural waste stated above and also using new initiatives such as the plantation of Jatropha trees among other energy plants. The availability of agricultural residue in the country is been identified in the assessment. The Gambia has the potential to cultivate large-scale farms on energy crops for biofuel production such as Jatropha which is a good oilseed. Good national biofuel policies and strategies implementation need to be put in place to be able to achieve these goals. The research assessed the available feedstock that produced biodiesel and bioethanol processed from some sub-Saharan African countries. The Gambia can invest in the same initiatives to produce biofuel and in collaboration with country experts that have been in the biofuel production.

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