JKAU: Eng. Sci., Vol. **34** No. 1, pp: 1 – 22 (2024 A.D.)
DOI:10.4197/Eng.34-1.1

Enhancing Energy Access: Mapping Biomass Resources for Sustainable Development in Nigeria

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Abstract Nigeria, a major producer of petroleum in the world is currently grappling with a serious energy insufficiency as result of inactivity of her four petroleum refineries often repeated disruptions of the national electricity grid. Importation of refined petroleum products to address the energy shortage has not brought the desired relief as the subsidy regime keeps making the intervention more difficult to interpret for active participation of key players. The natural gas pipeline failure has not been of help because consumers daily seek for alternatives to natural gas utilization due to regular insufficient pressure to meet demand requirements. These, coupled with several challenges associated with fossil fuels utilization including climate change, require that Nigeria embraces biomass as an additional key driver to increase her energy mix. An extensive literature review has been carried out in this paper to identify the major biomass available in the country while their characteristics and spatial distribution are also reported. The technology required for harness to achieve significant intervention so that the present hardship facing Nigerians in accessing energy carriers that will meet up with their demand can be mitigated is identified and reported. The paper concludes that huge benefits await Nigeria if her abundant biomass resources can be trapped into the energy basket of the country.

***Keywords*:** Energy; Biomass; Mapping; Generation

1 Introduction

The perennial energy shortage in Nigeria calling for improved energy mix in the country continuously points to the need for conscientious efforts towards biomass consideration to address this challenge. Though several interventions have been activated for the control of energy shortage in Nigeria, there seems to be no end at sight as the gap between energy demand and supply keeps widening on daily basis. Electricity supply from the national grid is not improving while shortage of refined petroleum products is not abating. Also, natural gas supply from the national gas pipeline is not meeting consumers' demands thus consumers continue to aggressively look for alternatives so that the energy crisis can be controlled. Nigeria being a major player in the global crude oil affairs with over 37 billion barrels proven crude oil reserves (Figure 1), it would be expected that energy demand can be easily met but the reverse is the case.

Presently Nigeria has four petroleum refineries located in Warri, Port Harcourt I, Port Harcourt II and Kaduna with total installed capacity of 445,000 bbls/day but the increased domestic demand of refined petroleum products has put excessive pressure on their refining operations making them insufficient even when working at full capacity [2]. Udonne and Akinyemi

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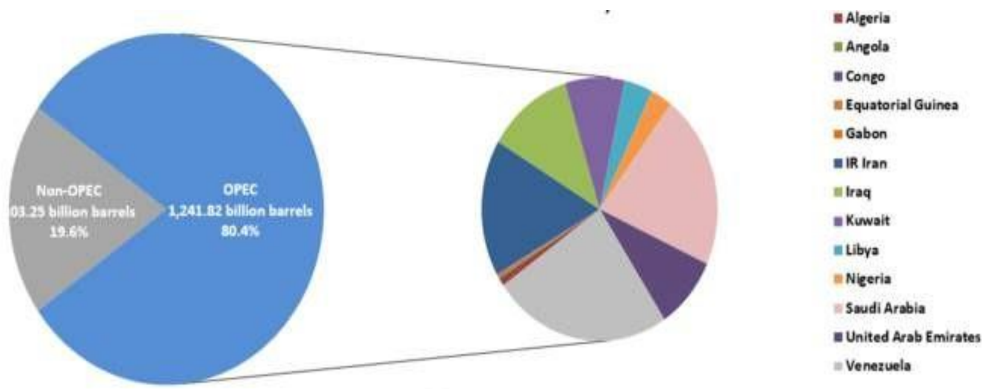
[3] reported that the refineries were functioning poorly due to age, poor maintenance, weak governance and vandalisation of the pipelines supplying crude oil to them, which have affected their production capacities but even now, none of these works as they are all reported to be under Turnaround Maintenance (TAM) making refined petroleum products supply from them impossible. Several efforts to get improved local petroleum refining are yet to produce meaningful results while the 650,000 bbls/day Dangote Refinery recently commissioned may not be of meaningful help due to the several neighbouring countries that rely solely on the country for their refined petroleum products supply. Similarly, the electricity available in the national grid has remained stagnant at about 4000 MW though the installed capacity is about 10,775 MW [4].

This is even very far from the 30,000 MW electricity demand of the country reported by Sonibare [5]. Though Nigeria has about 180,490,000 MMcf of gas reserves ranking her 9th in the world and produces about 3,009,650 MMcf ranking her 12th globally, it consumes only about 664,628 MMcf in a typical year making her to be ranked 38th among the natural gas consuming nation. PWC [6] reported that Nigeria ranked fourth place globally in natural gas exports and controlled about 7% of the total global export of natural gas as at 2017.

From the above narrations, it can be summarized that though Nigeria is an active player in fossil fuel reserves, production and export, it lacks capacity to process the same for local consumption to solve her energy shortage crisis. This might have contributed to the reason for the country's continuous search for other sources of energy including biofuel, which is presently attracting global attention due to its advantage of carbon conservation, among others. In 2005, the Federal Government of Nigeria through the Nigerian National Petroleum Corporation (NNPC), initiated the Automotive Biomass Program for the country to facilitate the development and adoption of biofuels [7]. This led to the birth of the Nigerian biofuel policy and incentives, a government whitepaper for promoting biofuels in Nigeria.

The white paper provides a broad policy platform for promoting the development and adoption of biofuels as well as fast tracking the investment in biofuels value chain from feedstock production to biofuel refining and distribution with a set-target of 10 years for attaining full fuel blending. This eventually gave birth to the country's biofuel policy in 2007 with the aim of spurring a vibrant bioenergy sector. Though Ohimain [8] reported that there are many conflicts, gaps and inconsistencies in the Nigeria biofuel policy, this has been found as the best special purpose vehicle commissioned for biofuel intervention on how the on-going energy crisis in the country can be addressed. The policy has therefore confirmed the country's readiness to engage biomass as an energy carrier for its improved energy generation. These renewable organic materials from plants and animals are presently



OPEC proven crude oil reserves , at end 2021 (billion barrels, OPEC share)

Venezuela	303.47	24.4%	United Arab Emirates	111.00	8.9%	Algeria	12.20	1.0%	Equatorial Guinea	1.10	0.1%
Saudi Arabia	267.19	21.5%	Kuwait	101.50	8.2%	Angola	2.52	0.2%			
IR Iran	208.60	16.8%	Libya	48.36	3.9%	Gabon	2.00	0.2%			
Iraq	145.02	11.7%	Nigeria	37.05	3.0%	Congo	1.81	0.1%			

Figure 1: Nigeria Crude Oil Reserves among OPEC Nations at End 2021 [1]

utilized globally to address energy shortage. Also, the use of biomass fuels for transportation and electricity generation is increasing in many developed countries to avoid carbon dioxide (CO_2) emissions from fossil fuel consumption.

For numerous reasons, biomass utilization is rapidly embraced globally though with many challenges including low energy density, low calorific value, and high logistic costs as reported by Cambero and Sowlati [9]. Nuno et. al [10] reported Peru's adoption of improved biomass cook stoves (ICS) as cooking technologies to increase wellbeing and reduce household air pollution in the country. China and India have shown exponential growth in biomass development and adoption for energy intervention, followed by USA, Germany, and UK [11]. At national, institutional and personal levels, Nigeria has been active in ensuring that biomass if profitably engaged in mitigating her energy crisis. One of the steps taken to accomplish this is the setting up of the Energy Commission of Nigeria (ECN), through the enabling Act No. 62 of 1979, as amended by Act No. 32 of 1988, Act No. 19 of 1989 and the Energy Commission of Nigeria Act Cap E10 LFN 2004. In its National Energy Policy developed for the country, the commission identified the biomass resources of Nigeria to include wood, forage grasses and shrubs, animal wastes and wastes arising from forestry, agricultural, municipal and industrial activities, as well as aquatic biomass. It has also estimated the biomass energy resources of the nation to be significant. The objectives of the commission on biomass include promotion of biomass as an alternative energy resource especially in the rural areas; promotion of efficient use of agricultural residues, animal and human wastes as energy sources; reduction of health hazards arising from utilization of biomass; and focus of biomass utilization close to production, for community heating schemes and domestic heating, particularly off the national grid network [12].

Also in the country for improved biomass utilization in energy generation is the National Biotechnology Development Agency (NABDA) established in 2001 under the Federal Ministry of Science and Technology, to implement policies, explores resources, conducts research, promotes, coordinates and develops of biotechnology in Nigeria. The Agency, among others, has in place a bioenergy development programme designed to adapt anaerobic digestion technology for biogas production. The Agency "has developed prototype digesters and enhanced bioenergy biochemical procedure for improved biogas generation from biodegradable organic feedstock. It is also into collaboration with the Rural Electrification Agency (REA) to develop integrated energy system that includes biomass conversion to electricity in selected facilities across the country. There are many research efforts on-going in the country for improved biomass utilization in energy generation. Ben-Iwo et al [13] identified the various biomass resources that can be utilized for transportation fuel in the country while Okafor et al [14] reported some biomass resources that can be utilized for power generation in Nigeria. Ndukwa et al [15] proposed that if the wide energy in Nigeria shall be successfully, bridged, the country must embrace biomass utilization for biofuel production. Oseni [16] had also earlier identified the need to identify more biomass resources for improved households' access to electricity and energy consumption pattern in the country. Sambo [17], while confirming the presence of abundant biomass resources in Nigeria, identified the need for increased penetration of these resources to get more energy supply mix. There have been numerous studies on biodiesel production from biomass resources in the country though with different requirements to bring them to commercial levels. For example Ajala et al [18] reported the need for some parameters modification if palm kernel oil based biodiesel production with meaningful profit margin shall be accomplished. Oke et al [19] insists that proximate analysis is a necessary pre-condition for charcoal from some Nigeria biomass resources to be safely utilized for energy generation.

The objective of this work is to identify the major biomass available in the country and characterize them with their spatial distribution reported. It is also to determine the technology required for harnessing the biomass to achieve significant intervention in the present energy crisis facing the country. The paper determines the benefit awaiting the country from trapping her abundant biomass resources into the present energy basket for expansion and improved energy provision.

2. Nigeria Biomass Availability for Bioenergy Generation

There are several documented efforts on identification of biomass resources for energy generation in Nigeria. Biomass resources for biofuel production can be in form of first, second, third and fourth generation biomass feedstocks. The first generation biofuels are those derived from food crops including sugar or starch-based crops and oilseeds to produce bioethanol or palm oil for the production of biodiesel. Through fermentation or trans-esterification, these biomass feedstocks are processed into bioethanol or biodiesel respectively. Second generation biomass feedstocks include crop residues, wood residues and dedicated energy crops which are primarily cultivated for the purpose of biofuel production. These biomass feedstocks are increasingly gaining interest globally as sustainable alternative to fossil fuels because they are not food crops thus not in competition with food. The third generation biofuels are known as "algae fuel" or "oilage" because they are produced from the algae leading to the production of all types of bio-fuels with yield higher than the second generation biofuel. Saad et al, [20] reported that these generation of biofuels can meet the global demand for sustainable fuel production. There is also the fourth generation biofuels feedstock which encompasses the use of genetic engineering to increase desired traits of organisms used in biofuel production. It applies to a variety of traits from utilizing multiple types of sugars (e.g., pentoses and hexoses), to higher lipid synthesis or increased photosynthesis and carbon fixation. However Cavelius et al [21] reported that there are still challenges to achieve large-scale industrial implementation of this fourth generation biomass feedstocks conversion.

Nigeria's climate and topography favour the presence of all the identified four generations of biomass feedstocks for energy generation in the country. Its location in the tropical zone gives it a wide climatic variation with maximum Temperatures of about 32 °C and high relative humidity. This climate is characterized by the dry and wet conditions associated with the movement of the Inter-Tropical Convergence Zone (ITCZ) north and south of the equator. The ITCZ appears as a band of clouds that circle the globe near the equator. When it is to the south of the equator, the northeast winds prevail producing the dry-season and whenever it moves into the northern Hemisphere, the southwest wind prevails to bring rainfall and the rainy season. The wet season is generally from April to October, with generally lower temperature, and a dry season from November to March, with midday temperatures that surpass 38 C but relatively cool nights. Rainfall is continuous in the country during the month of August, after which a short dry season often referred to as the "August break" sets in. In the southern part of the country, precipitation is heavier, especially in the South-East, which receives between 2,000-3,000mm of rain per year, compared with about 1,250-2,500mm in the South-West. Rainfall decreases progressively away from the coast, with the far North receiving not more than 600 mm per year (Figure 2).

The total area of about 90,989,000 Ha constituting land and water (Figure 3) in Nigeria makes it possible as a country to have some of these four generations biomass feedstocks in abundance. Its major Rivers of about 9,040 km long (Table 1) indicate that the country has potential to cultivate some of these feedstocks in certain regions if so desired.

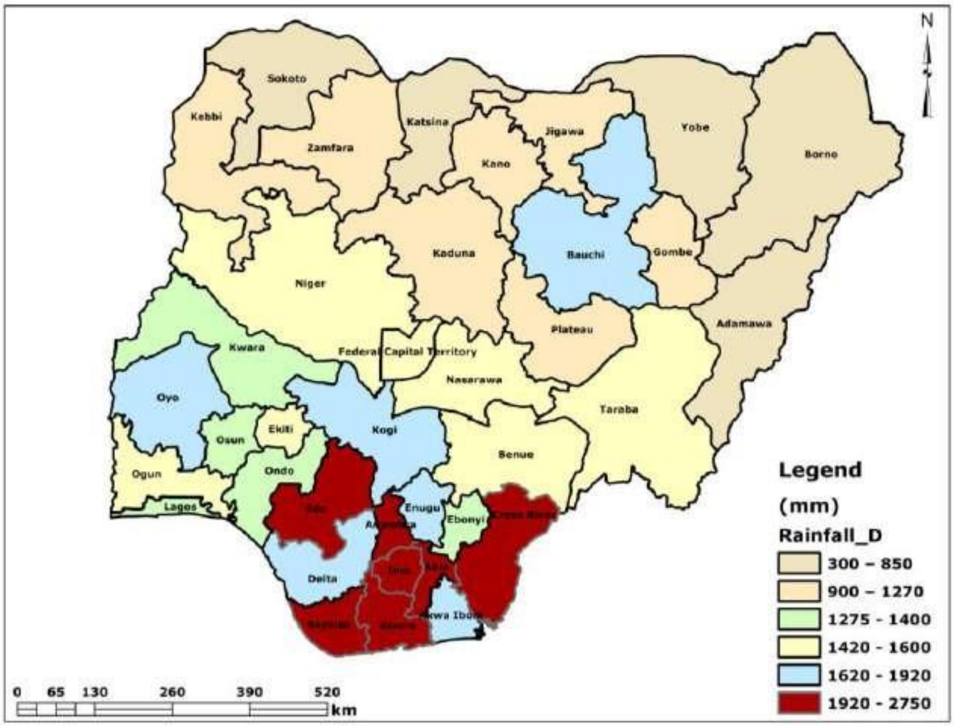


Figure 2: Rainfall Distribution inNigeria

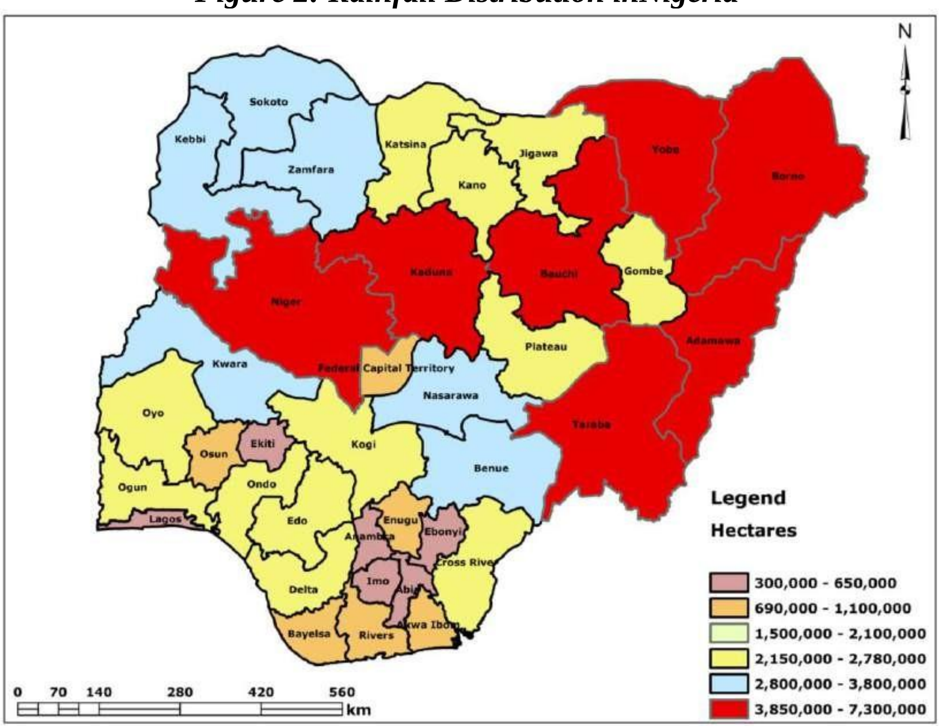


Figure 3: Land Coverage Area in Nigeria by State

Table 1: Major Rivers in Nigeria

Rivers	Length in km	State
Anambra	209.2	Anambra and Enugu
Benue	796.5	Benue
Cross River	539	Cross River
Donga	281.6	Taraba
Gongola	350.9	Northeastern states
Hadejia	329.8	Jigawa
Imo	225.3	Imo
Ka	378.1	Zamfara
Kaduna	547.1	Kaduna
Katsina-Ala	345.7	Benue
Komadugu Yobe	466.6	Yobe
Mariga	297.7	Niger
Mada	201.1	Nasarawa
Mungo	168.9	
Ngodela	289.6	
Niger	1174.6	Niger Delta States
Ogun	305.7	Ogun
Oni	153.9	Ogun
Osun	273.5	Osun
Osse	265.5	Ekiti
Sokoto	627.5	Sokoto
Yesderam	353.9	Borno
Yewa	120.7	Ogun
Zamfara	337.8	Zamfara

NBS (2019)

2.1. First Generation Biomass Feedstocks in Nigeria

There are several food crops thriving very well in the country and which fall in to first generation biofuels feedstocks. Some of these presently in commercial quantity and on which there can be improved production for the objective of bioenergy production from biomass to be achieved in Nigeria are summarized in Table 2 with a typical annual production rate. These range from 97,149 – 57,643,271 tons with the minimum from cashew (0.07%) and the maximum from cassava (40.31%). Though these are food products thus their utilization for biofuel generation may result in food shortage in the country, their wastes may be very useful for biofuel generation. They are all sugar or starch-based crops and oilseeds required for bioethanol or palm oil for the production of biodiesel as earlier indicated.

Cashew grows in areas with about 20 – 30 °C and annual precipitation of about 1000 – 2000 mm, among other climatic requirements. It is produced in about 75% of the country with over 91,000 metric tons production in 2018 (Figure 4). Biodiesel is produced from palm oil considered an alternative and promising feedstock to further diversified the biodiesel production in the global market. Because palm oil contains various phytonutrients that can be separated out prior to biodiesel production, these are reported to have a high market value that can thus offset the overall palm biodiesel production. As presented in Figure 5, palm oil is produced in about 25 States of Nigeria and the FCT at about 380 – 160,000 metric tons with the minimum and maximum from FCT and Akwa- Ibom State respectively.

Due to its abundance and relative ease of conversion to ethyl alcohol (ethanol), corn (Zea mays) is a popular feedstock for ethanol production. It is produced in all the States of the country (Figure 6) and if intentionally cultivated for biofuel production, it may not compete with food production in the country because its production presently stands at 54,000 – 750,000 metric tons per state with total annual product of about Ten Million Metric Tons in a typical year. Nigeria is ranked 14th largest maize producer globally. Stamenković et al [23] identified Sorghum as a unique energy crop for biofuel production as all its parts can be used as sustainable feedstocks through various production routes like starch or sugar-to-ethanol, cellulosic/lignocellulosic-to-bio-oil, biochar, biogas, or bio hydrogen, and oil-to-biodiesel. Nigeria produces about 6 million metric tons in a typical year with the minimum and maximum from Kwara and Kano States respectively (Figure 7). This ranked her as the global second largest producer of sorghum. Cassava, another major first generation source of biofuel is another crops produced in large quantities across the country (Figure 8). The country produced about 65 million metric tons with the minimum from Zamfara and the maximum from Cross River States. These rank her as the world largest producer of the crop [24]. The cassava stem contains both hemicellulose and cellulose as fermentable sugars in the form of lignocellulose making it to serve as feedstock to produce both first- and second-generation biofuels.

Table 2: Crops Production in Nigeria in 2018

Crop	Production (Tons)	Contribution (%)
Cashew	97,149	0.07
Cotton seed	277,523	0.19
Cocoa	302,066	0.21
Soya Beans	588,523	0.41
Palm oil	1,405,967	0.98
Sugarcane	1,449,963	1.01
Millet	1,485,387	1.04
Cocoyam	3,182,128	2.23
Groundnut	3,467,446	2.42
Beans	3,588,819	2.51
Rice	6,256,228	4.38
Guinea corn	7,005,025	4.90
Maize	10,562,050	7.39
Yam	45,677,939	31.94
Cassava	57,643,271	40.31
Total	142,989,484	100

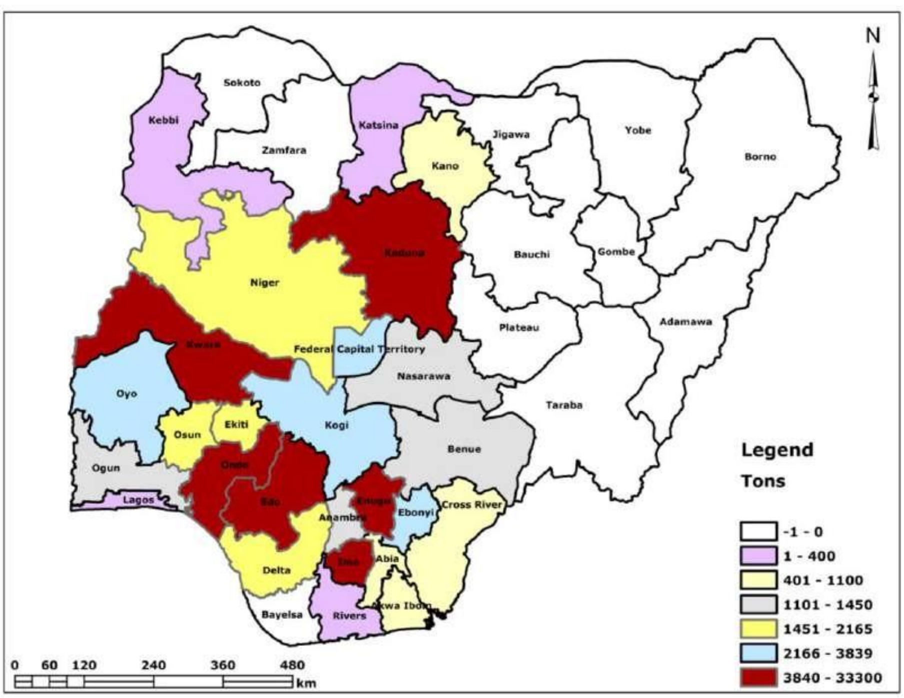


Figure 4: Cashew Prodction in Nigeria by State (Developed from [22])

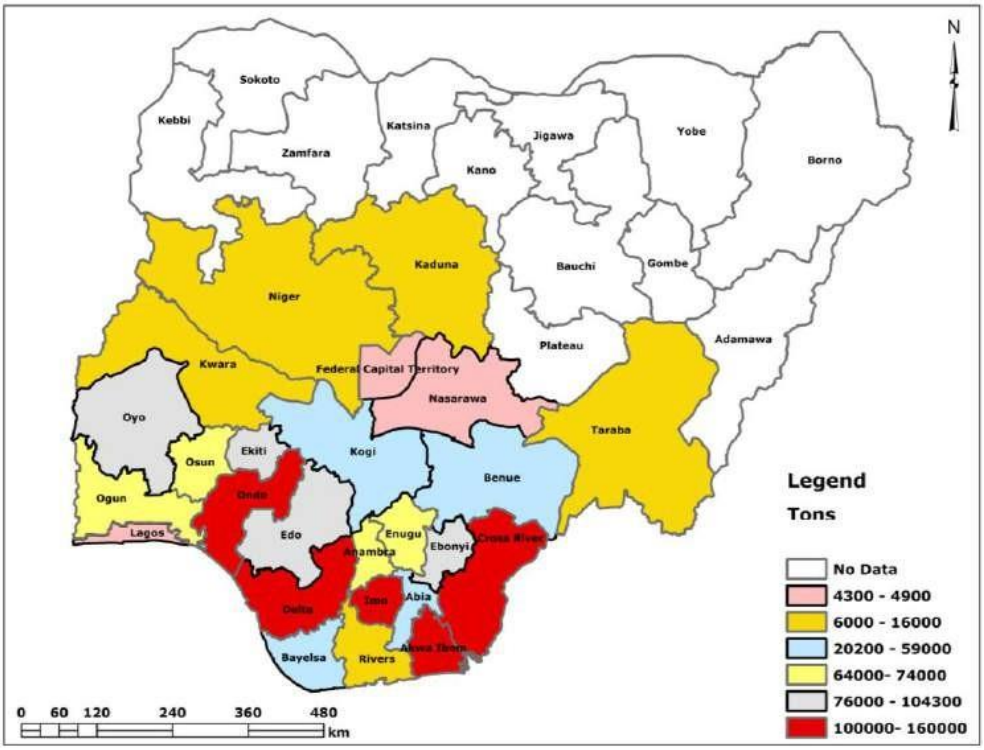


Figure 5: Oil Palm Prodction in Nigeria by State (Developed from NBS, 2019)[22]

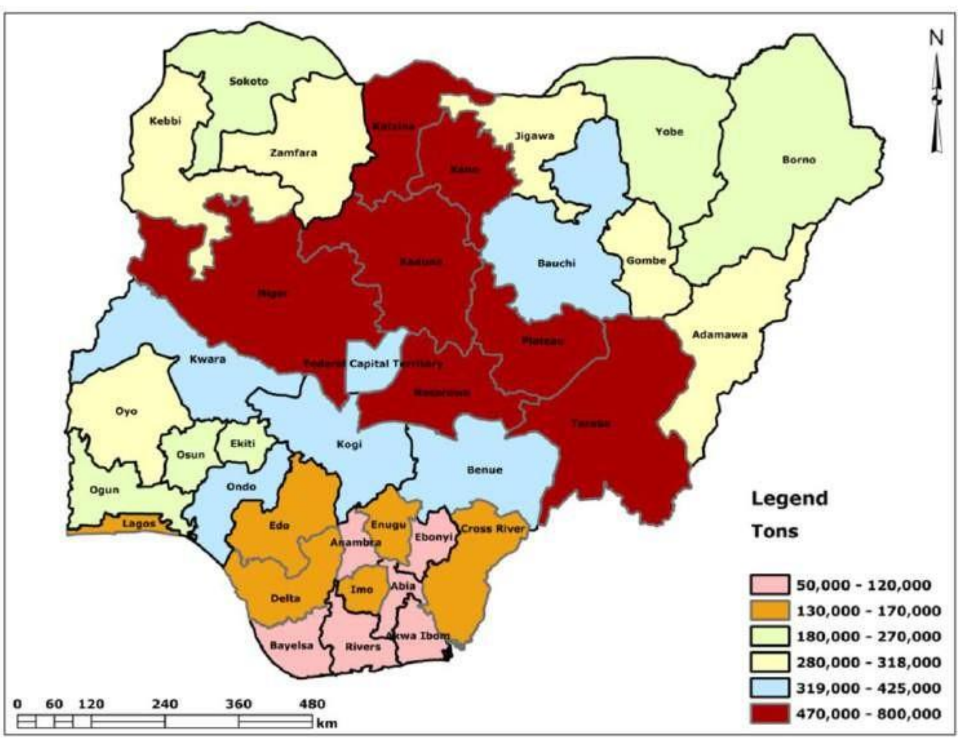


Figure 6: Maize Prodction in Nigeria by State (Developed from [22])

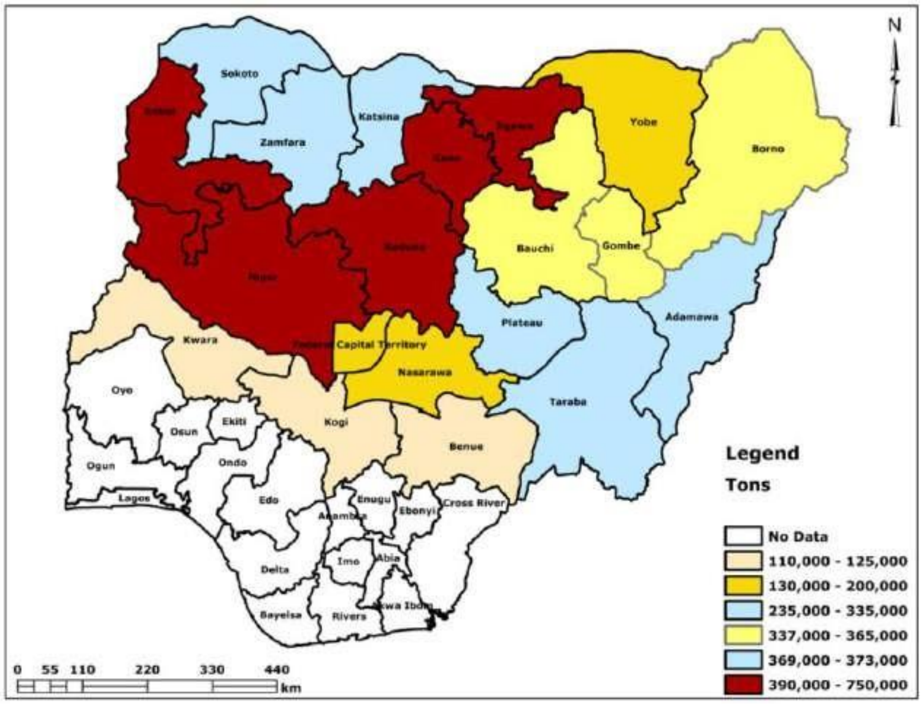


Figure 7: Sorghum Prodction in Nigeria by State (Developed from [22])

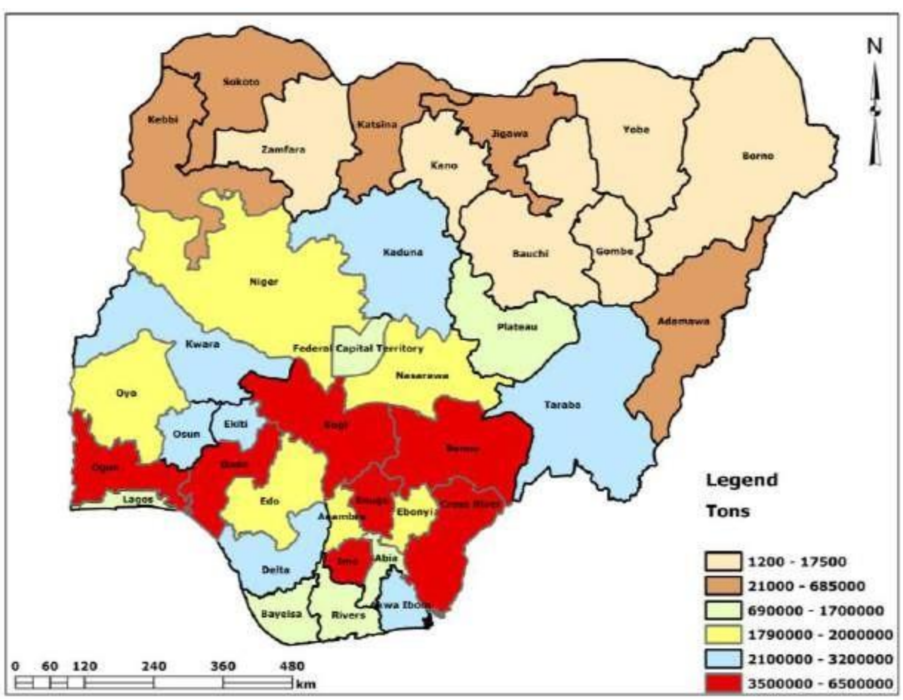


Figure 8: Cassava Production in Nigeria by State [22])

2.2. Some Nigeria's Second Generation Biomass Feedstocks

As indicated earlier, second generation biomass feedstocks are crop residues, wood residues and dedicated energy crops primarily cultivated for the purpose of biofuel production. In addition to the agricultural land available for crops production, Nigeria has forest reserve of about 8,345,727 Ha (Figure 9) with about 812,000 Ha developed into plantation. Most of these forests have biomass of different forms presently used for biofuel and adequately documented. Though a common food staple in Nigeria, straw and husk from rice are common sources of biofuel and Nigeria has these in abundant. Sharma et al [25] reported about 1.5 tons of rice straw per ton of rice produced. It has been identified as one of the abundant lignocellulosic biomass with potential as a feedstock for bioethanol production. Also if converted to ethanol, rice husk can be utilized as biofuel. For every 1 kg of rice produced, approximately 0.28kg of rice husk is generated [26]. These, no doubt, indicates that Nigeria presently has abundant of these second generation biomass feedstocks for biofuel production. Presently produced in all the 36 States of the country and the Federal Capital, Nigeria presently produces of 10 million Metric Tons of rice (Figure 10). From these there is abundant rice straw and rice husk in the country waiting for effective utilization in biofuel production.

A major cash crop in Nigeria, cotton, is grown in the Savannah belts of the country which is the Northern & South Western Nigeria such as Kano, Kaduna, Oyo, Ondo, Kwara, Katsina, Jigawa, Ogun, Kebbi, Sokoto & Zamfara states (Figure 11). Its production in 2018 was about 213,000 metric tons but with capacity for improved yield if given adequate attention. Though found useful in textile and other areas of manufacturing, its seed has been found very useful in biofuel production. Nigeria ranks 23rd largest producer of cotton in the world. Found predominantly in the southern part of the country, cocoa is produced in commercial quality in Nigeria (Figure 12). Its annual production is between 20 and 80,000 metric tons with the minimum and maximum in Imo and Ondo States respectively. According to Mendoza-Meneses et al [27], cocoa industrial wastes including cocoa pod husk, mucilage, and bean shells, contain lignocellulose though which requires a pretreatment for utilization as biofuels depending on the conversion technology used to obtain the highest biomass yield.

Several other agricultural wastes from the food crops initially discussed in first generation biomass feedstocks are abundant in the country. For example, corn cob, a waste product of corn contains large amount of sugars that can be further utilized to produce biofuel. Sugarcane has great potential for biofuel production and Nigeria has it in abundance. Sugarcane bagasse has also been confirmed as a major lignocellulose feedstock for biofuel production due to its high organic content and biomass yield as well as ease of collection and storage. With about 3 tonnes of wet bagasse from 10 tonnes of crushed sugarcane, Nigerian annual sugarcane production of about 1,500,000 metric tonnes produce about 450,000 metric tonnes (Table 2). Groundnut shells composed of cellulose, hemicellulose and lignin thus can be converted to bio- products including biodiesel and bioethanol. With its shells accounting for about 20% of the dried peanut pod by weight [28], Nigeria can generate about 600,000 metric tons of shell residual left after her over 3,000,000 annual metric tons groundnut processing. While Lagos is the least groundnut producing State in Nigeria, Bauchi is the highest (Figure 13). Wheat straw is another major agricultural wastes abundant in Nigeria. Like other lignocellulosic biomass, there is the need for wheat straw pretreatment followed by hydrolysis for biofuel production from these wastes. Its about 88,000 metric tons produced in the country (Figure 14) in a typical year can allow some significant level of wheat straw generation for biofuel production.

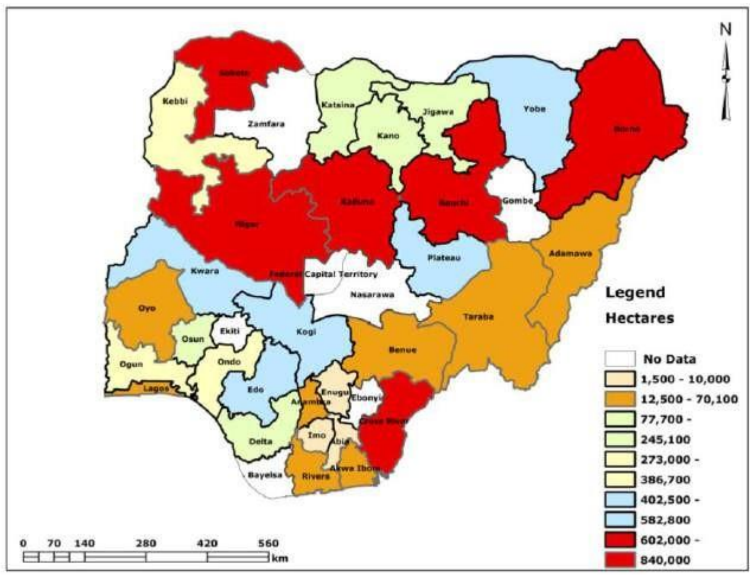


Figure 9: Forest Reserves in Nigeria by State (Developed from [22])

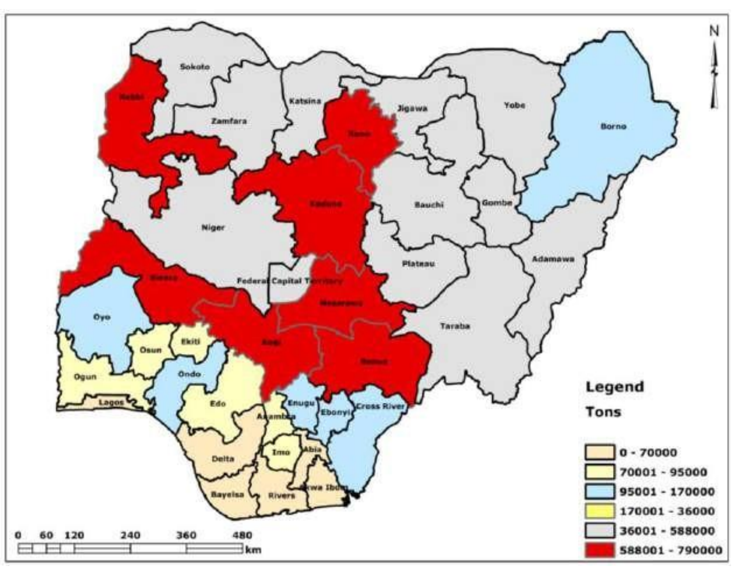


Figure 10: Rice Production in Nigeria by State (Developed from [22])

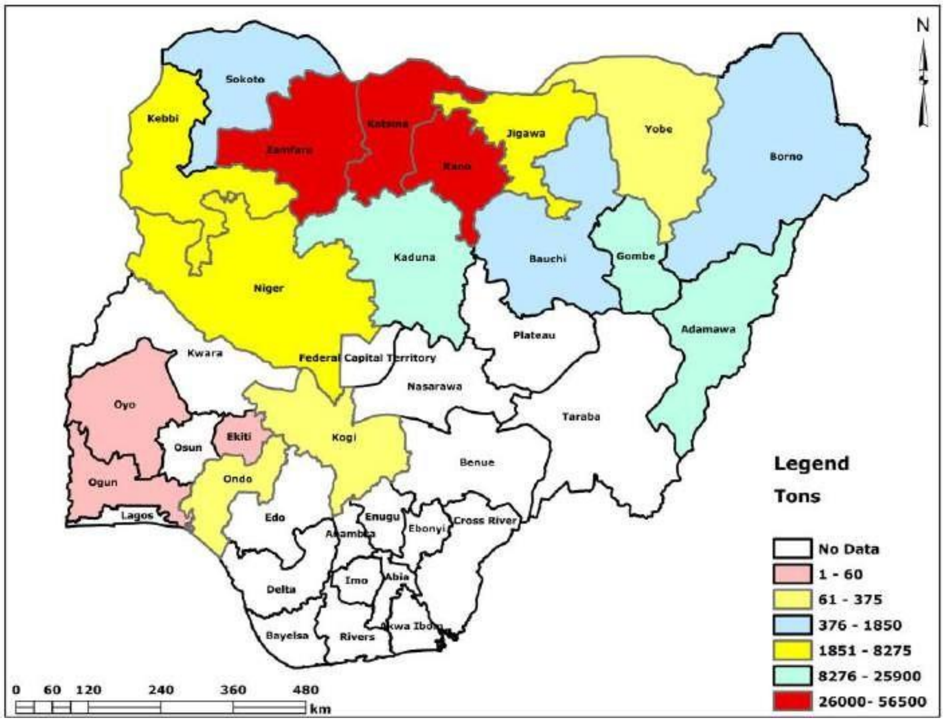


Figure 11: Cotton Production in Nigeria by State (Developed from [22])

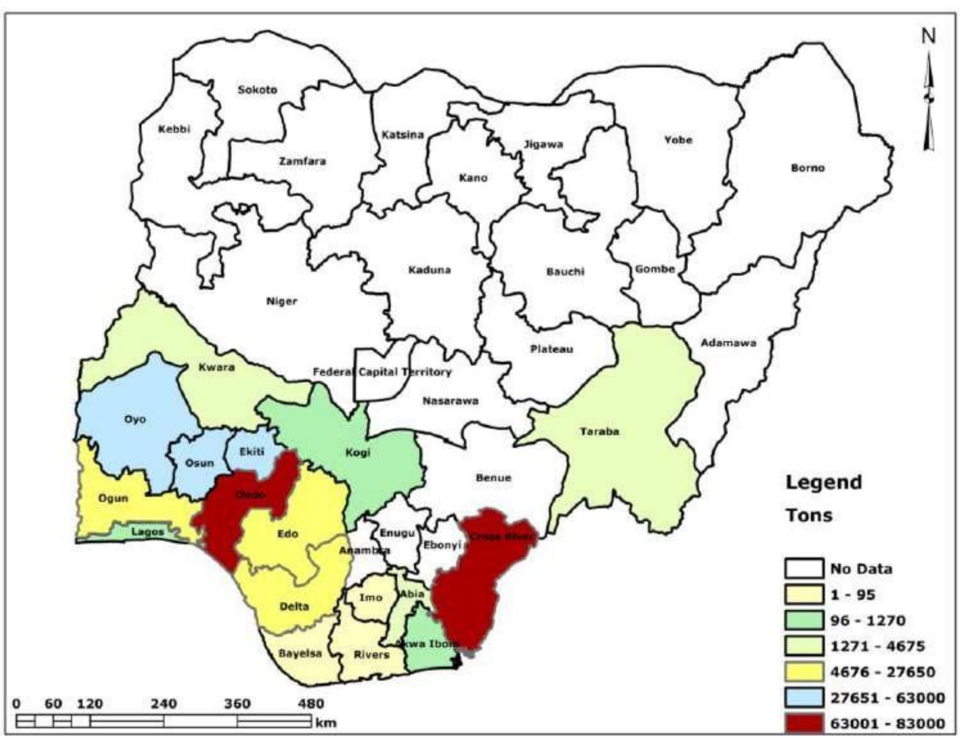


Figure 12: Cocoa Production in Nigeria by State (Developed from [22]

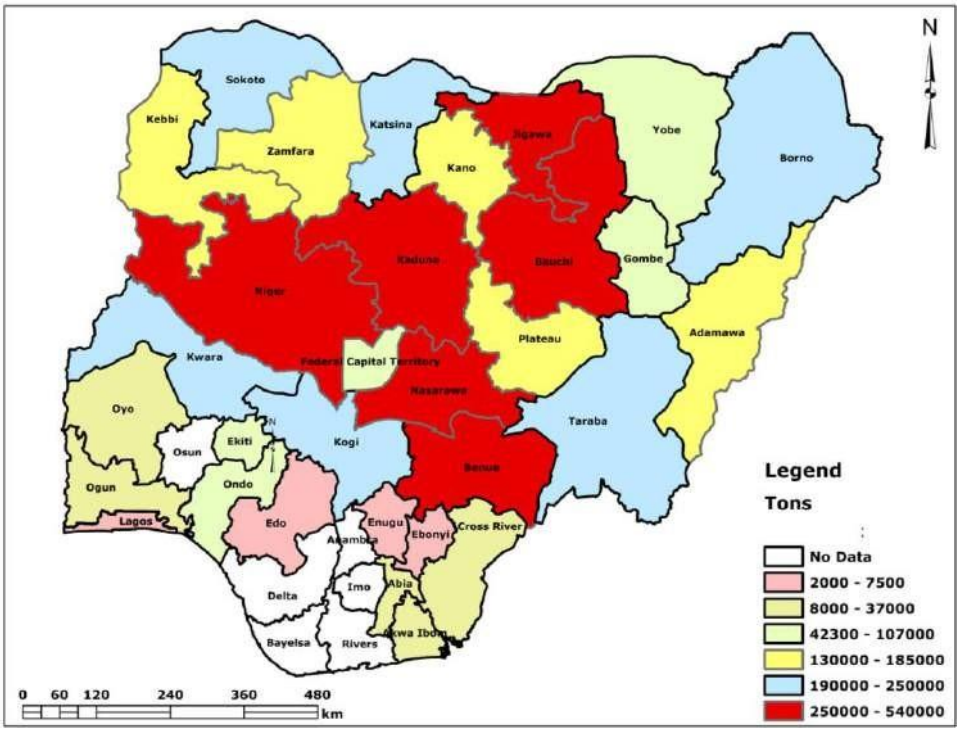


Figure 13: Groundnut Production in Nigeria by State (Developed from [22])

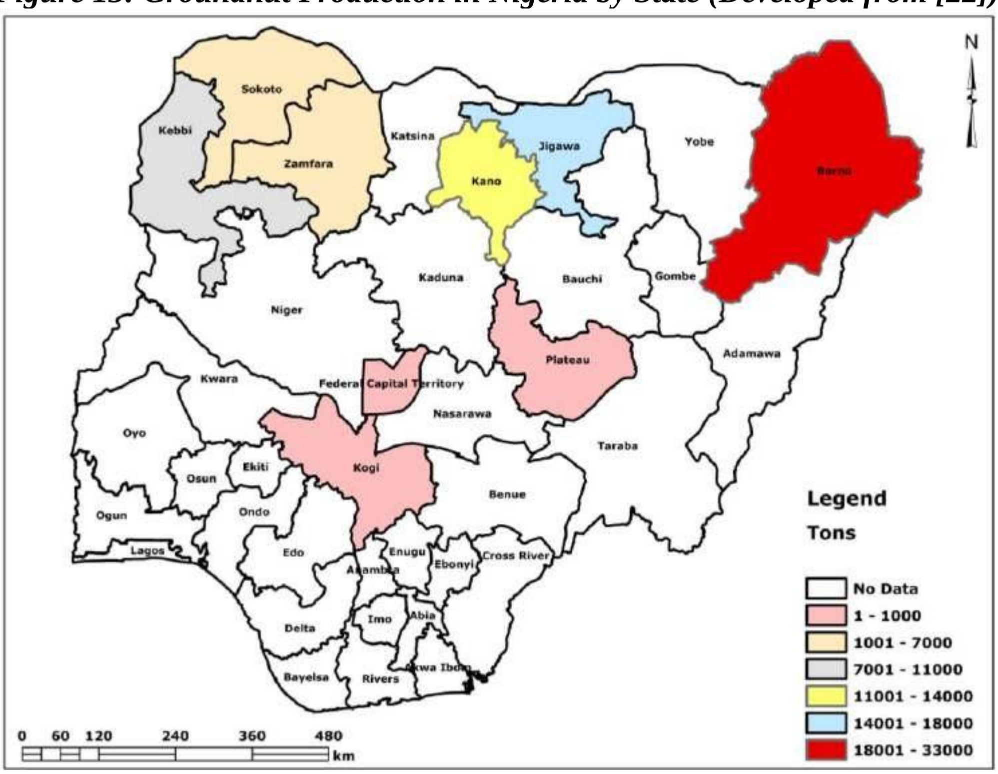


Figure 14: Wheat Production in Nigeria by State (Developed from [22])

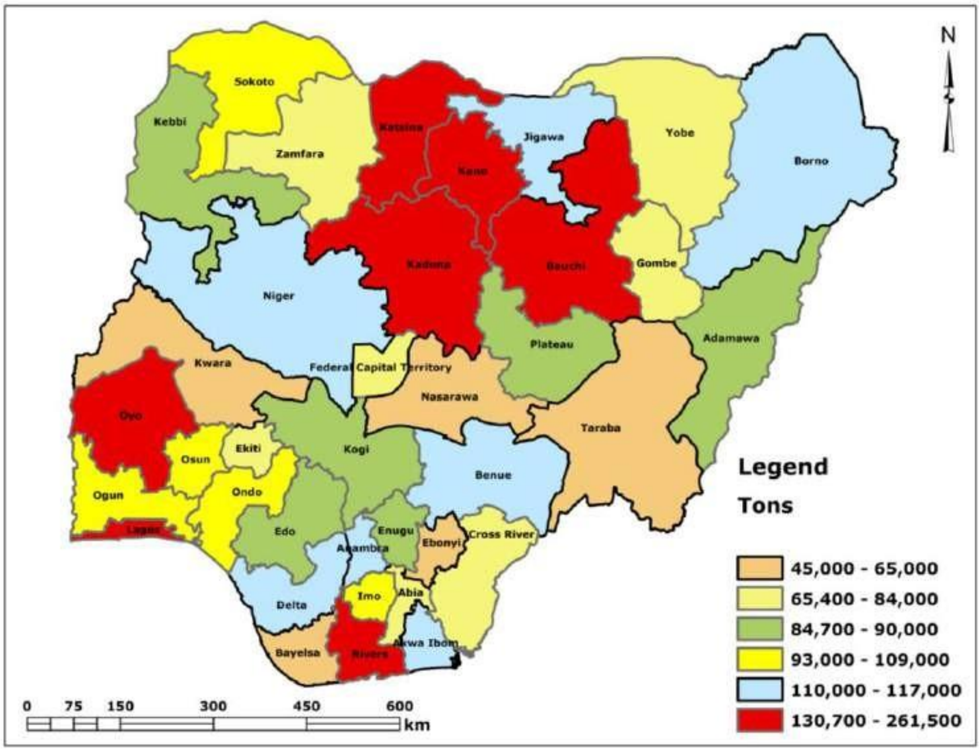


Figure 15: Municipal Solid Wastes in Nigeria by State (Developed from [22])

When municipal solid waste (MSW) are burnt in waste-to-energy plant, steam can be produced in a boiler to power an electric generator turbine. When these MSWs are buried in landfill, microbes present in the land can act on the dumped materials and decompose the organic content present thus forming landfill gas. This contains about 50% of CH_4 and 50% CO_2 which can be harvested as biogas. Nigeria's over 3,000,000 metric tons municipal solid wastes spread across the States and FCT (Figure 15) can be utilized for biogas production if properly harnessed.

In addition to its biogas generation, studies have reached advanced stage about how poultry litre can be converted to biomass feedstock for biofuel generation. Poultry production is about 120,000,000 in the country (Figure 16) comprising of chicken, guinea fowl, duck, and turkey, among others (Figure 17) can make wastes from this sector be of interest in biofuel production. Similarly, the over 252,000,000 livestock production in a year (Figure 18) signifies the presence of animal wastes including dung, in commercial quantity for biofuel production in the country. These are made of cattle, goat and camel among several others (Figure 19). Properties of Nigeria's common Biomass Feedstocks as in the global biofuel production, what characterize the first generation of biomass feedstock are high carbohydrate, high starch contents or vegetable oil potential. Nigeria's biomass feedstock of the first generation are also not different from these. Since processing these elements to become biofuel requires biochemical treatments for vegetable oil to biodiesel or starch and sucrose to ethanol. Several studies in the past have reported that the first generation biomass feedstock in Nigeria also possess these properties thus making their conversion into biofuel to be easily accomplished.

3. Technology Requirements for Nigeria's Biomass Processing

Conversion of biomass feedstock already identified in Nigeria into biofuel requires some level of technological handling and processing.

3.1 Biochemical Conversion

Generally, biomass is composed of three major components including cellulose, hemicellulose, and lignin. For fuel production from these compounds, there is the need for biochemical conversion processes which may involve breakdown of the hemicellulose components of the biomass for the reaction to be more accessible to the cellulose, while the lignin components remain unreacted. Using a thermochemical conversion process, the lignin can be recovered and used as fuel. Biochemical conversion involves two main processes: anaerobic digestion and fermentation.

Anaerobic digestion is a biochemical conversion suitable for energy production from agricultural residues and other biodegradable wastes. In this process, high-moisture content (85–90%) biomass is converted by microorganisms in the absence of oxygen to produce a mixture of carbon dioxide (CO_2), methane-rich gas (biogas), and other gases such as hydrogen sulphide. Biogas produced from anaerobic digestion has an energy content that is about 20–40% of the lower heating value of the biomass feedstock. Nigeria presently uses anaerobic digestion primarily on agricultural residues, animal waste and other wastes in Nigeria for fertilizer and biogas production.

There is also fermentation used in the conversion of biomass feedstock to biofuel. It is an enzymatic controlled anaerobic process which is the third step in the production of bioethanol from lignocellulosic biomass. This approach requires that raw biomass is first pre-treated and hydrolysed before fermentation. Enzymatic hydrolysis converts the cellulose component of the biomass into glucose but the hemicellulose component is converted into pentose and hexoses before the glucose is fermented into ethanol by selected microorganisms.

Biofuel is also produced by alcohol transesterification of large branched triglycerides into smaller straight-chain molecules of, for example, methyl esters with enzyme, acid or an alkali as catalyst. The resulting fatty acid methyl esters (FAME) are then mixed with fossil diesel. Wood extractives consist of vegetable oils and valuable chemicals which can be converted to biodiesel by transesterification with methanol.

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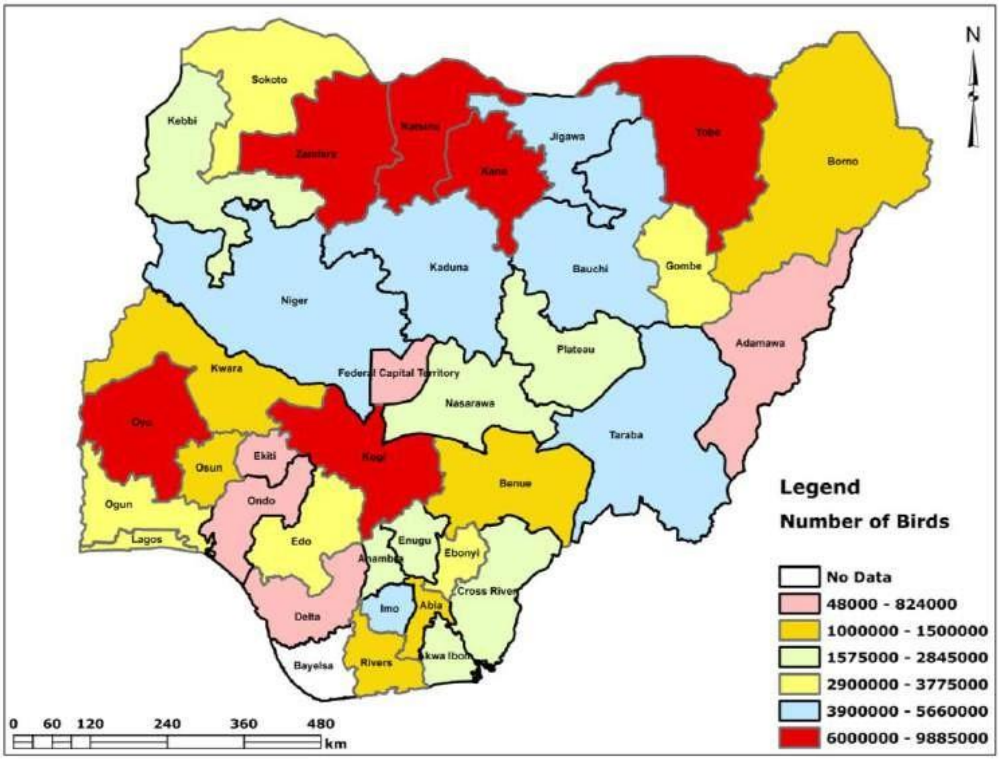

Figure 16: Poultry Production in Nigeria by State (Developed from [22])

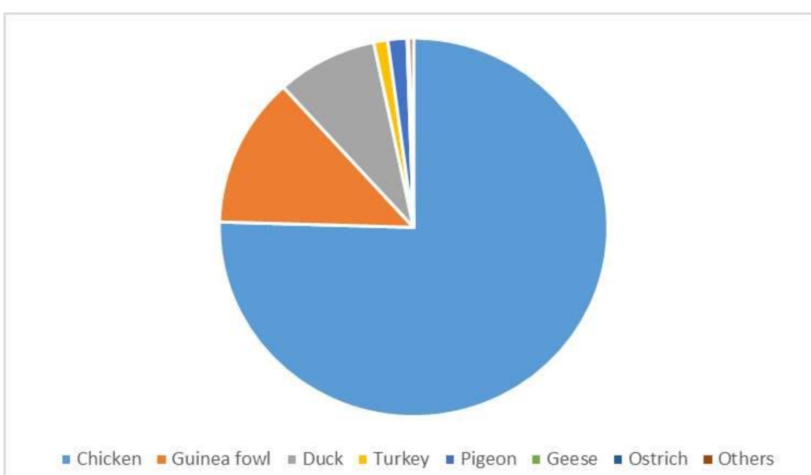

Figure 17: Nigeria's Poultry Distribution by Type

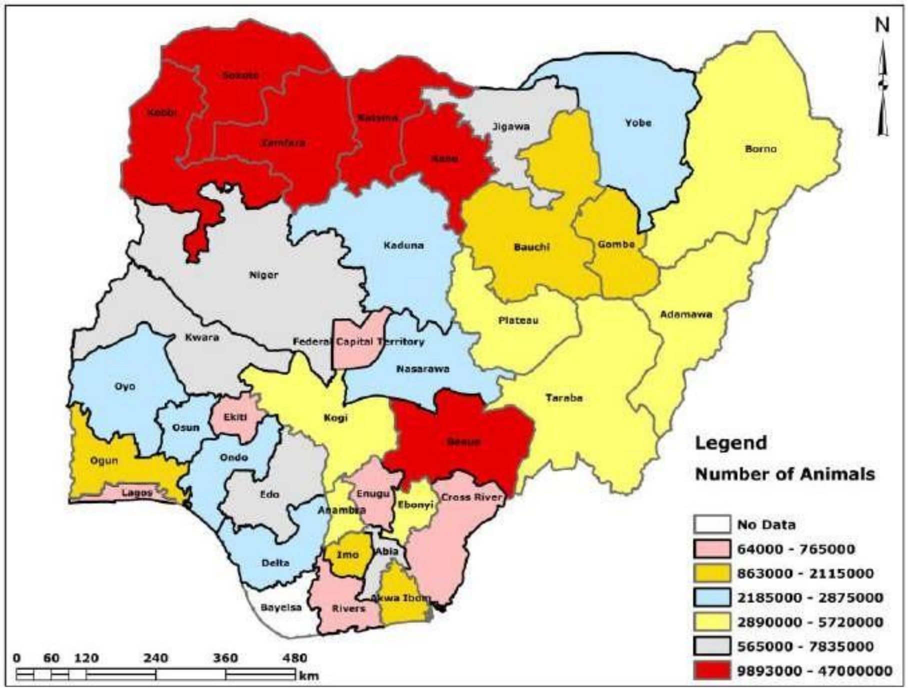

Figure 18: Livestock Production in Nigeria by State (Developed from 22])

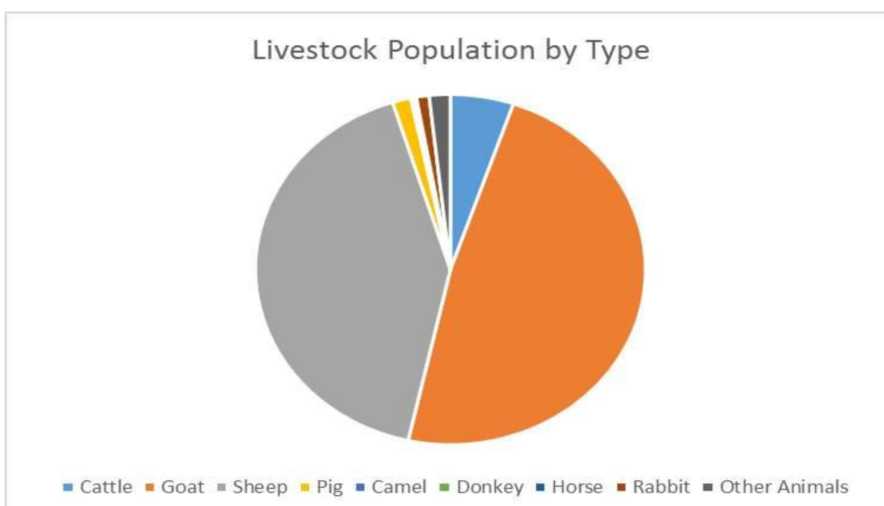

Figure 19: Livestock Production by Type in Nigeria

3.2 Thermochemical Conversion

In biofuel production, thermochemical conversion processes involves more extreme temperature than that used in biochemical conversion. Examples include direct combustion, pyrolysis, gasification and liquefaction.

There is direct combustion which is the most common way of extracting energy from biomass. It can be applied to several fuel materials in the first and second generation biomass feedstock earlier indicated. This conversion method is not used for biofuel production but provides energy in the form of heat and electric power.

Pyrolysis is another major biomass conversion process that is precursor to combustion or gasification of solid fuels. It involves thermal decomposition of biomass at temperatures of about 350–550 °C, under pressure, in the absence of oxygen. Generally this process produces three fractions including liquid (bio-oil), solid (predominantly ash) and gaseous fractions.

There is gasification which is the partial oxidation of biomass into a combustible gas mixture at temperatures of 800–900 °C. The gas produced is known as synthesis gas (syngas) consisting of a mixture of carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), traces of other light hydrocarbons (C_5H_{10}), steam (H_2O) and nitrogen (N_2).

4 Conclusions

This study has identified the major biomass available in Nigeria while their characteristics and spatial distribution have been reported. The technology required for harness to achieve significant intervention so that the present hardship facing Nigerians in accessing energy carriers that will meet up with their demand can be mitigated is identified and reported. It can be concluded that huge benefits await Nigeria if her abundant biomass resources can be trapped into her energy basket as they are all there in abundant.

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تعزيز الوصول إلى الطاقة: رسم خرائط موارد الكتلة الحيوية من أجل التنمية المستدامة في نيجيريا

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مستخلص. تعد نيجيريا، أحد أهم منتجي النفط في العالم و رغم ذلك تعاني حاليًا من نقص خطير في الطاقة نتيجة لعدم كفاءة مصافيها النفطية الأربع حيث غالبًا ما تتكرر الاضطرابات في شبكة الكهرباء الوطنية. إن استيراد المنتجات البترولية المكررة لمعالجة نقص الطاقة لم يحقق الانفراج المنشود.كذلك فشل خط أنابيب الغاز الطبيعي جعل المستهلكين يبحثون يوميًا عن بدائل لاستخدام الغاز الطبيعي بسبب الضغط غير الكافي المنتظم لتلبية الاحتياجات. وتتطلب هذه التحديات، إلى جانب العديد من التحديات المرتبطة باستخدام الوقود الأحفوري بما في ذلك تغير المناخ، أن تتبنى نيجيريا الكتلة الحيوية كمحرك رئيسي إضافي لزيادة مزيج الطاقة لديها.

في هذه البحث تم إجراء استعراض واسع النطاق لتحديد الكتلة الحيوية الرئيسية المتاحة في البلاد مع توصيفها وتوزيعها المكاني و كذلك دراسة التكنولوجيا اللازمة لتسخير هذه المصادر بحيث يمكن تخفيف الصعوبات الحالية التي تواجه النيجيريين في الوصول إلى ناقلات الطاقة التي ستلبي طلبهم. ويخلص البحث إلى أن فوائد ضخمة تنتظر نيجيريا إذا أمكن حصر و دراسة مواردها الوفيرة من الكتلة الحيوية في سلة الطاقة في البلاد.

الكلمات الدالة: مصادرالطاقة، الكتلة الحيوية، انتاج الطاقة