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An Analysis of the Impacts of Bioenergy Development on Food Security in Nigeria: Challenges and Prospects

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***Abstract* – Fossil fuel such as coal, natural gas, oil and recently shale gas are perhaps the most economically viable means for energy generation but are laden with inexhaustible environmental consequences. Thus, biofuel development has received tremendous support from all quarters in response to quest for energy security and clean energy. However, the rapid rate of development of bioenergy has also raised concern chiefly for its nexus with food security with some scholar considering it a disaster especially for countries in the global south. Due to her prime location along the equator, and the generally favourable climatic conditions all through the year, Nigeria is considered to have enormous potential for bioenergy development. Unfortunately, Nigeria is also highly ranked in the 2018 Global Hunger Index (GHI) of International Food Policy Research Institute (IFPRI). Rested mainly on exploratory approach, this study analyses the bioenergy potential of Nigeria and the implications of the fast-rising market on food security in the Nigerian context. Critical investigation on the food crop-bioenergy trade-offs was conducted while bioenergy development implications were analysed in the context of the four dimensions of food security. Lastly, mitigative measures to bioenergy development impacts were discussed and one key proposition is need to strengthen the second and third generation technology for biofuel production in Nigeria.**

***Keywords* – Bioenergy; biofuel; energy crop; energy security; food security; food–energy competition**

1. INTRODUCTION

There is no doubting the tremendous role that bioenergy will play in shrinking the global emission of greenhouse gases especially from fossil fuel burning and engendering industrial revolution [1]. The world has a lot to gain at large but how much will it benefit the developing nation particularly in sub-Saharan Africa where most of these resources are to be generated. Between the years 2000 and 2007 global biofuel production has tripled and this rate is expected to be sustained or even surpassed within the foreseeable future [2]. This surge reflects the increasing global interest in bioenergy as sustainable alternatives to fossil fuels [3]. It also

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emphasizes some of the successes of the Kyoto Protocol implementation in 2005, and the growing acceptance and adoption of national biofuels targets.

However, the growing demand for bioenergy products has also recently began to raise questions on the threat which this energy drive portends to food security, particularly in most developing nations where food security is considered a major challenge, and has led to a phenomenon now referred to as 'food-versus-fuel' debate. In fact, this debate has in the recent years made energy generation from biomass unpopular amongst some scholars. This is fervently reflected in the report of Jean Ziegler, a United Nation independent expert on the right to food, where he describes bioenergy development as a "crime against humanity" and "growing "catastrophe" for poor people" in a UN Special Rapporteur. His perspective is informed by the growing food shortages and soaring food prices, leaving millions of poor people in the developing countries hungry [4], [5]. Zafar [6] and Osseweijer, et al. [7] on the other hand have a contrary opinion to Jean Ziegler's theory, though the importance of good governance is emphasized. They asserted that energy from biomass only offers a win-win alternative for rural communities especially in the global south, through opportunity for clean energy production, improved utilization of agricultural wastes, creation of more job opportunities and improved health. Bioenergy development can also significantly improve food production and the economy of the rural communities [6], [7]. As many African governments are dedicating more and more of their land to the biofuels cultivation, the question begging for answers are: is Africa ready for this? How sustainable is this drive in the light of the potential consequences on their huge vulnerable populations, environments and states across the continent?

Based on existing data, Nigeria has an enviably enormous potential for biofuel production because of the vast availability of water and arable land with fertile soils [8]. Nigeria is also a party to various international environmental agreements relating to Climate Change, Ozone Layer Protection, Hazardous Waste, Desertification, Endangered Species, Law of the Sea, Marine Life Conservation, Marine Dumping, Ship Pollution, Wetlands [9]. Thus, it is justifiable for Nigeria to embark on projects such as energy production from biomass which will promote a healthier and friendlier environment. However, the transition to economic and industrial growth and low carbon emission in Nigeria will possibly be hampered by a number of factors. These factors as opined by Oshewolo [9] include amongst others lack of political will, conflicting and inconsistent policies, poor inter-agency coordination and implementation of policies, inadequate infrastructure and high industrial production cost, high level of financial malpractice and corruption, and poor public awareness. These are germane issues which must be address if Nigeria is to succeed in its bioenergy quest

The Nigerian quest for bioenergy has stimulated a vastly polarized views among stakeholder in the bioenergy industry. This situation stems from the assumption that biofuel development constitutes a substantial threat to food security especially since such energy crops as cassava, corn, soya beans, oil palm, sorghum as well as sugarcane are also regarded important staple food crops in Nigeria [9]. Here, this research will be looking at the impacts of bioenergy quest in Nigeria on food security through the spectacle of the four pillars of food security, but first how does it affect land use as well as supply and price of food crops?

2. METHODOLOGY

This study is built on the secondary exploratory research approach by reviewing existing literature and other data phenomenon that reveals possibilities for further evaluation of research interest as has been adapted by Reiter [10] and Elegbede, et al. [11]. Researches may be investigated using exploratory, descriptive and explanatory methods. Exploratory studies attempt to discover new intuition by considering research questions that would lead to better understanding of the knowledge [12]. This type of research method considers the criticality of the situations where research questions directly connect to the research problems.

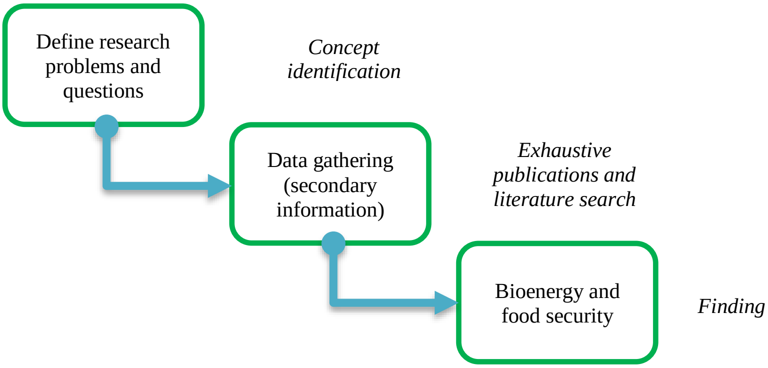

Fig. 1. Exploratory research approach (adapted by authors).

This research begins with the formulation of theory and research questions, afterwards engage in critical investigation of the topic. Furthermore, problems were formulated, idea clarification, sorting and gathering were considered including reflection on insight. Data were also collected based on exploratory review of secondary materials including journal articles and reports to critically evaluate relevant information specific to the research question and objective (Fig. 1). In order to investigate this research, the research starts by reckoning at bioenergy potentials in Nigeria; engaging in analysis of food crops-bioenergy trade-offs in Nigeria and the exhibition of the four dimensions of food security in the context of bioenergy; this study finally made enquiry on how to mitigate the impact of bioenergy development. Afterwards, the findings and discussions were discussed simultaneously.

3. Results and Discussion

3.1. Bioenergy Potentials in Nigeria

Nigeria is considered one of the most promising countries in the world in terms of bioenergy potentials considering her vast amount of bioenergy resources which contributes about 78 % of the national primary energy supply [13]. Biomass resources available in Nigeria include: fuel wood, agricultural waste, forest and crop residue, sawdust and wood shavings, industrial effluents/municipal solid waste, animal dung/poultry droppings. The enormousness of Nigeria's biomass resources is emphasized by the nation's vegetation. The rain forest in the south generates the highest amount of wood-based biomass while the guinea savannah vegetation of the north central region generates more crop residues than the Sudan and Sahel savannah zones. Also, it is a common knowledge in Nigeria that different regions in the country are known for the kind of crops they majorly produce as illustrated in Fig. 2. Municipal wastes are also generated in the high-density urban areas such as Lagos and Kano [14]–[16]. Aliyu & Deba [17] categorized the major biomass feed stocks in Nigeria into energy crops, agricultural crop and forest residues, municipal solid wastes and fuel woods and are discussed below.

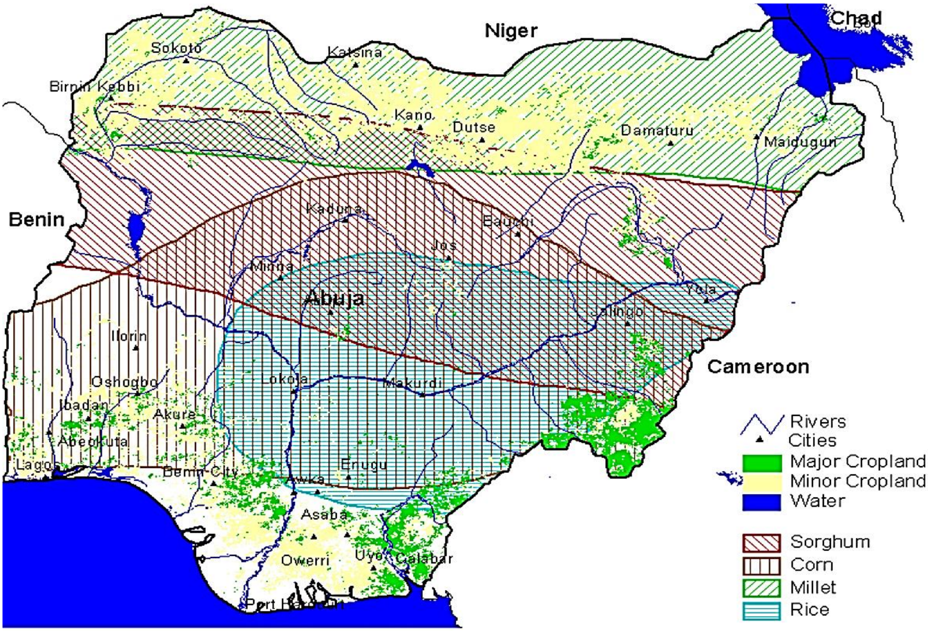

Fig. 2. Major crop zones in Nigeria [17].

3.1.1. *Energy Crops*

These are agricultural crops specifically grown as fuels for energy production. They include oil plants, trees and grasses. Trees considered as energy plants are those that can still reproduce even after being cut off close to the ground and can be harvested every 3–8 years for a period of 20–30 years such as willow, poplar (*Populus spp*) and eucalyptus. Grasses used for the purpose of energy production are often thin-stemmed-grasses which can grow both in hot and wet climates such as sugar cane, sweet sorghum, elephant grasses and phalaris [18]. The common energy crops in Nigeria include sugar cane, rice, maize, cassava and sorghum for ethanol and oil palm, groundnut, cotton, coconut, soya bean, jatropha and sesame also locally referred to as “biniseed” for biodiesel.

Recently, interest in the use of jatropha for energy production has grown because it is a non-edible crop. Also known as *Lapalapa* in Yoruba, *Bini da zugu* in Hausa and *Wuluidu* in Igbo, Jatropha is a multipurpose shrub which grows wildly with little or no maintenance in Nigeria. The two common species found in Nigeria are *Jatropha curcas* and *Jatropha glandulifera*. Because Jatropha curcas is a tough and perennial plant that can grow under varying climatic conditions and soil-types, it is grown in all part of the country and supports intercropping. Jatropha seeds have around 30 to 40 % oil content, and depending on the typology of the seed, can produce up to about 3 000 L of oil per hectare. The oil content can be used directly as fuel and may be further processed into biodiesel. The distribution, management, harvesting and uses of energy crops have not been properly documented in Nigeria [14]. Table 1 below shows the estimated biofuel production potential of some major energy crops in Nigerian in 2017 based on data from the FAO.

TABLE 1. NIGERIA'S BIOFUEL PRODUCTION FROM SOME ENERGY CROP, 2017 [19]

Crop	Production quantity, tonnes	Average yield, tonnes/ha	Biofuel type derivation	Derivable biofuel yield, litres/ha
Sesame	550 000	1.1	Biodiesel	696
Groundnut	2 420 000	0.8582	Biodiesel	1 059
Soybean	730 000	0.9733	Biodiesel	446
Coconut	288 615	7.3768	Bioethanol	2 689
Sugarcane	1 497 757	16.8255	Bioethanol	6 000
Cassava	59 485 947	8.7578	Bioethanol	4 000

3.1.2. Agricultural Crop Residues

Organic residues generated from agricultural crop production as by-product during the harvesting and processing are referred to as agricultural crop residues [14]. They are biomass wastes produced during agricultural farming activities such as straw, bagasse and poultry litter [18]. Such agricultural wastes generated either in the form of on-the-farm crop wastes like cornstalks or as processing waste like rice husk, corn shells, palm kernel shell and cassava peels form significant sources of fuels. Though, they are mostly directly burned locally as starter or supplement to fuel wood, these residues can be further processed for their higher energy contents [20].

Agricultural residues generated during harvest are called primary, field based or simply crop residues while those generated at the stage of processing are referred to as secondary or process-based residues or Agro-industrial by-products. Agricultural residues are heterogeneous in nature with varying bulk density, moisture content, particle size and distribution depending on the mode of handling. They are characterized by high fibre and low nitrogen content. Field based residues are usually used as fertilizer or for erosion control and sometimes as fodder for livestock [14], [21]. In Nigeria, the common crop or field-based residues are straw, leaves and stalk of cereals crops such as rice, millet, maize/corn, sorghum, groundnut, and stalk/peelings yam and cassava as well as cocoa pods [15], [22]. However, almost 50 % of these field-based residues are burnt on the cropland before the commencement of anew planting season. Process based residues on the other hand, offer higher potential for energy and include husk and/or shell of crops like cocoa, coconut, rice as well as oil seed cakes, bagasse of sugar cane and oil palm empty fruit bunch. The chemical composition of a crop residue depends largely on such factors as variety of crop residues, age of crop harvest, physical composition of the residues such as the length of storage and system of harvesting [14]. Table 2 presents the proximate compositions of some major crop residues in Nigeria.

TABLE 2. PROXIMATE COMPOSITION OF COMMON CROP RESIDUES IN NIGERIA [14]

Crop residue	Moisture content, %	Crude protein	Organic matter	Crude fibre	Ether extract	Ash	Nitrogen free extractives
Maize stover	10	2.8	85–91	28–46	1–2	9–15	35–53
Sorghum stover	10	3–6	96	31–35	1–2	4	50–56
Rice straw	10	2–9	75–90	20–45	1–4	10–25	29–48
Groundnut haulms	10–12	11–17	87–90	21–29	1.5–2.5	10–13	51–57
Cassava tops	70–80	17–27	89–90	8–26	3–8	6–11	35–60
Sugar cane tops	70–80	5–8	81–95	28–34	1.5–2.5	5–9	44–54
Cocoa pods	75	2–9	75–90	20–45	1–4	10–25	33–56
Empty oil palm fruit bunch	56	3–4	95	–	6–8	5	–

3.1.3. Forest Residues

Forest residues are waste woods or residues generated from logging of trees and wood-processing operations in the forest [15] and may range from materials like forestry trimmings, wood chips, sawdust to tree barks [18]. Forest residue can either be logging residues or wood processing residues also called primary mill residues. Logging residues results from accumulation of unused materials usually left in the woods during logging activities. Such materials may include tree branches, leaves, stumps, off-cuts, and sawdust. Wood-processing residues are generally generated when round woods are processed into final wood products at the sawmill, veneer mill, plywood mill, or pulp mill. Wood processing residues may include materials wood shavings, sawdust, discarded logs and bark. Forest residues have high potential for the generation of electricity, heat, liquid fuels and solid fuels such as pellets, briquettes, or charcoal briquettes [15].

According to Agbro & Ogie [15], 100 tonnes of timber can generate up to about 42 tonnes of sawdust which put the potential for annual sawdust generation in Nigeria at about 1.8 million tonnes. Presently, this form of bioenergy is poorly exploited in Nigeria thus wood waste constitutes an important source of environmental problem. The estimate of Nigeria's forest and wood processing residues for 2010 is presented in Table 3.

TABLE 3. FOREST AND FOOD PROCESSING RESIDUE IN NIGERIA, 2010 [14]

Type	Residues	Percentage of residues	Total residues, tonnes
Logging	Solid wood	40	2 196 956
	Dust	20	1 098 478
Sawmilling	Sawdust	12	659 087
	Solid wood	38	2 087 108
Plywood	Solid	45	60 732
	Dust	5	6 748
Particle board	Dust	10	9 640
Wood fuel total			158 466 244

3.1.4. Municipal Solid Wastes (MSW)

Municipal solid wastes are wastes generated from household, industrial and commercial sources. MSW can be unsegregated i.e. mixed or segregated (glass, metal paper etc.) [18]. Millions of tonnes of these wastes are collected every year with vast majority ending up in landfill dumps Including plastics, paper, textiles, glass, metal, wood, and other organic waste [15]. Municipal solid waste can also be in its ‘as produced’ (original) form or may be densified to form a pellet; commonly referred to as dRDF (densified Refuse derived Fuel) [18]. Agbro and Ogie [15] stated that about 25 million tonnes of municipal solid waste are generated yearly in Nigeria. Table 4 presents waste generation rates and breakdown density in Nigeria urban areas. The table shows that the waste generation rates in Nigeria’s major cities ranged from 0.66–0.44 kg/cap/d while in most developed countries cities the rate is 0.7–1.8 kg/cap/d. The waste generation rate is greatly influenced by the population economic power thus; it is typically low for low income towns.

TABLE 4. SOLID WASTE GENERATION IN NIGERIA'S MAJOR CITIES, 2007 [15]

City	Population	tonnage/month	Density	kg/capital/day
Lagos	8 029 200	255 556	294	0.63
Kano	3 248 700	156 676	290	0.56
Ibadan	307 840	135 391	330	0.51
Kaduna	1 458 900	114 433	320	0.58
Port-Harcourt	1 053 900	117 825	300	0.60
Makurdi	249 000	24 242	340	0.48
Onitsha	509 500	84 137	310	0.53
Nsuka	100 700	12 000	370	0.44
Abuja	159 900	14 785	280	0.66

Energy can be generated from municipal solid waste either by direct combustion, or by natural anaerobic digestion on the landfill. The gas produced on land fill sites as a result of the natural decomposition of MSW which is composed of approximately 50 % each of methane and carbon dioxide is collected from the storage facility for scrubbing and cleaning before being fed into either the internal combustion engines or gas turbines for onward generation of heat and power. Furthermore, the organic composition of the municipal solid waste can be stabilized through anaerobic process in a high-rate digester to produce biogas to either generate electricity or steam [15]. In Nigeria, biogas digester technology has been domesticated and a couple of pilot biogas plants have been installed in various strategic locations. Examples of installed biogas digesters in Nigeria include human waste-based biogas plant installed in the Zaria prison; cow dung-based biogas facility installed at the Fodder farm of the National Animal Production Research Institute (NAPRI) also in Zaria, Kaduna and another in Mayflower Secondary School Ikenne, Ogun State. There is also an 18 m^3 capacity pig waste biogas facility installed in the piggery farm of the Ojokoro/Ifelodun Cooperative Agricultural Multipurpose Society in Lagos. Presently, more indigenous organizations are investing in economically viable systems for generating various energy forms from municipal waste [20].

3.1.5. Fuel wood

Fuel wood has been the most commonly used domestic renewable energy resource especially in rural Nigeria and by low income groups in the urban areas [15]. The total fuel wood consumption in Nigeria in 1985 was 87.587 million m^3. In the year 2000, an estimated 55 million tonnes of fuel wood and charcoal were burnt, and it increased by 80 million m^3 ($43.4 \cdot 10^9$ kg) of fuel wood annually for cooking and domestic uses [23]. Within years 1989–2000, fuel wood and charcoal constituted between 32 and 40 % of total primary energy consumption in Nigeria. It was also estimated that national demand in 2000, was about 39 million tonnes of fuel wood. Around 95 % of the total fuel wood consumption was used for cooking in households and cottage industrial operations, including processing cassava and oil seeds, which are closely related to household activities. Only smaller fraction of the consumed fuel wood and charcoal was used in the services sector [20].

There is a direct relationship between human population and fuel wood demand, hence the cutting down of wet wood has been on the rise. The rate of consumption of fuel wood in Nigeria has now surpassed the production rate. It has therefore become an issue of concern if this resource can still be considered renewable [23]. Currently, improved wood stoves with different configurations and features are being promoted. The three-stone stove commonly used in the rural households which have efficiencies as low as 15 % has been going through different improvements. The ECN through its energy research centres at the University of Nigeria, Nsuka and Usman Dan Fodiyo University in Sokoto have been developing improved versions of the three stones stove locally. These improved versions can reduce fuel wood consumption by up to 50 % and are already being adopted in many states and by various organizations. One good example is the International Institute for Tropical Agriculture (IITA) cottage cassava industry at Moniya, Ibadan which have adopted these technologies [20].

Fuel wood presently constitutes the largest non-commercial energy resource in Nigeria (about 37.4 % of the total energy demand) and also dominates the non-electricity energy supply in the country. It is estimated that about 80 million m^3, equivalent to $43.4 \cdot 10^9$ kg (or 43.4 million tonnes) of fuel wood with an average daily consumption ranging from 0.5–1.0 kg of dry fuel wood per person is consumed every year in Nigeria for cooking and domestic purposes. The energy content of the fuel wood that can be used is ($6.0 \cdot 10^9$ MJ), but only between 5–12 % fraction this value is gainfully utilized for cooking and other domestic uses [15].

Table 5 shows the increasing trend in fuel wood consumption for domestic energy needs in Nigeria. The table shows an increase pattern of production and consumption of fuel wood for domestic and industrial purposes. The implication is an increase in the rate of deforestation to meet local energy demand.

TABLE 5. FUEL WOOD CONSUMPTION PATTERN IN NIGERIA (THOUSAND CUBIC METRES) [24]

Year	Total production	Household consumption	Industrial consumption
1997	152 433	110 194	31 069
1998	156 500	113 134	31 897
1999	156 516	113 145	31 901
2000	160 272	115 861	32 666
2001	163 959	118 526	33 418
2002	167 973	121 428	34 236
2003	172 098	124 410	35 077

2004	179884	127147	35848
2005	179754	129944	36667
2006	185357	133981	37789

Finally, although, biofuel production has been proven to be crucial to lower emissions of greenhouse gases and stimulate industrial growth, and Nigeria has an enviable potential for biofuel production considering the level of water availability and the vast arable land with fertile soils, scholars have sceptical about the consequences. There is a big doubt about the ability of Nigeria ensure its energy security through biofuels without undermining its food security and its environmental sustainability, since essential food crops such as cassava, corn, soya beans, oil palm, sorghum and sugarcane also constitute energy crops.

3.2. Food Crops-Bioenergy Trade-offs

3.2.1. Forest and Agricultural Land Use

Regardless of the positives, the growing bioenergy market in Nigeria may have sustainability risks. One of the concerns is the growing rate of use of agricultural and forest land for bioenergy crops production. Peskett, et al. suggests that rapidly growing population and the consequential increasing demand for food and biofuels will increase pressure on land. Even though Nigeria's bioenergy industry is still at the embryonic stage [25], large-scale mono-crop plantations of bioenergy crops are underway which are certain to cause competition with food crops for land, water, nutrient resources and other inputs while also leading to loss of natural habitats and further dispassion of invasive species population [26].

For example, Nigerian National Petroleum Corporation (NNPC)'s division of renewable energy in January 2007 commenced 4 major biofuel projects which covers about 90 000 ha. This was said to be the initial stage of the project. In pursuance of the mandate upon which the Renewable Energy Division was established, The Corporation sought for co-investors for the various joint ventures to enable it set off a large-scale biofuels industry in Nigeria. Within the same month the biofuel project was launched, the government of Ondo State, in Nigeria, had signed a Memorandum of Understanding with the NNPC to make use of various sites within the Okeluse forest reserve for ethanol production from cassava tubers [17], [27]. As at 2009, FOA already ranked Nigeria third globally in the production of biofuel feed stocks [8]. Based on the level of success achieved so far and realizing the enormous potential for biofuel production in Nigeria the NNPC has further partnered with both foreign and local investors to exploit the biofuel options and opportunities in Nigeria with over 146 000 ha already acquired for biofuel feed stock production as can be seen in Table 6 below [17]. Unfortunately, Nigeria is still considered to be in a serious hunger situation according to the 2018 global hunger index [28].

TABLE 6. ACQUIRED LAND BY NPC FOR PRODUCTION OF BIOFUEL FEEDSTOCKS IN NIGERIA [17]

Project	Cost, USD	Location	Owner/ operators	Feed stock	Feed stock, tonnes	Project summary production	Land hectare
Automotive Biofuel Project	306 million	Agasha Guma, Benue State	NNPC/Private Sector	Sugarcane	1.8 million	75 million L(ethanol), 116 810 metric tons (Sugar), 59 MW (electricity)	20 000
Automotive Biofuel Project	306 million	Bukuru, Benue State	NNPC/Private Sector	Sugarcane	1.8 million	75 million L(ethanol), 116 810 metric tons (Sugar), 59 MW (electricity)	20 000
Automotive Biofuel Project	306 million	Kupto, Gombe State	NNPC/Private Sector	Sugarcane	1.8 million	75 million L(ethanol), 116 810 metric tons (Sugar), 59 MW (electricity)	20 000
Automotive Biofuel Project (Kwali Sugar Cane ethanol Project)	80–100 million	Kwali (Federal Capital Territory	NNPC/Private Sector	Sugarcane	1.8 million	120 million litres (ethanol), 10–15 MW (electricity)	26 374
Automotive Biofuel Project	125 million	Ebenebe, Anambra State	NNPC/Private Sector	Cassava	3–4 million	40–60 million L(ethanol)	15 000
Automotive Biofuel Project	125 million	Okeluse, Ondo State	NNPC/Private Sector	Cassava	3–4 million	40–60 million L(ethanol)	15 000
Biodiesel 1	N/A	N/A	NNPC/Private Sector	Oil Palm	N/A	40 million L(biodiesel)	10 000
Biodiesel 2	N/A	N/A	NNPC/Private Sector	Oil Palm	N/A	40 million L(biodiesel)	10 000
Biodiesel 3	N/A	N/A	NNPC/Private Sector	Oil Palm	N/A	40 million L(biodiesel)	10 000

Additionally, the extent to which biofuels production can create competition for land and with food crops depends on the kind of energy crop in question. Land requirement for some energy crops are minimal relative to others [29]. For instance, Peskett, et al. [30], suggests that land requirement for sugarcane in sub-Saharan Africa is minimal, though this has not been proven. The energy crops with the highest potentials in Nigeria are cassava, palm oil and palm kernel. Cassava does not require so much land but palm kernel does mean more land will be required to for the energy crop plantation which deepens the competition for land even further. The conversion of natural lands, such as natural forests and wetlands into energy crops plantations for the production biofuels represents a significant threat to biodiversity, while large-scale ploughing of natural forests including peat land degradation can result in substantial release of captured carbon dioxide into the atmosphere [31], [32].

3.2.2. Food Production and Prices

Large scale bioenergy production can have both positive and negative implications on food security. For an instance, it is believed that if large-scale bioenergy is continuously produced from important food crops, the demand for such food crops will surge causing the prices to increase [33]. For example, the prices of agricultural commodity pushed up globally towards the end of 2006 and continued in this trend at even higher rate all through 2007 before stabilizing and then declining in early 2008. Many complex factors have been identified as the driving forces for the surge in food prices and both supply and demand factors were very significant. On the demand side, one of the key factors that have been identified is the enormous demand for major food crops including sugar, maize, cassava, oilseeds and palm oil from the bioenergy industry. This represents a major factor for the soaring prices of food crop in world markets. It is estimated that within 2007 to 2008 about 100 million tonnes of cereals (about 5 % of global cereal production) are being used for the production of biofuels [31], [34].

Organization for Economic Co-operation and Development (OECD) in its 2008 report projected that prices of food crops will continue to soar at even higher rate than before. It is predicted that the average prices of agricultural commodities will substantially rise higher for the period 2008–2017 with wheat, maize and skim milk powder rising up to 40–60 %; butter and oilseeds rising to over 60 % and vegetable oils over 80 % relative to the period 1998–2007. The increasing demand for energy crops is an underlying factor influencing this projection of the OECD as the demand for bioenergy constitutes the largest source of emerging demand for agricultural crops in decades and a major factor causing the upward shift in prices of agricultural commodities [31].

Most Nigerian farmers are net food-deficit producers or subsistent farmers, therefore diverting land and water away from food and feed production to energy crop production will likely lead to trade-offs for such farmers. As such, bioenergy development and its effects on poverty and food security has to be carefully considered.

3.3. Bioenergy in the Spectacle of Four Dimensions of Food Security

Food security is said to exist as according to World Food Summit, 1996, “when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” [35]. Analysing the nexus between biofuel and food security is a complicated task. Although it has been argued previously that the sharp growth in the demand for bioenergy feedstocks has contributed immensely to the current surge in food prices. The degree of price increment cannot be quantified and varies across the globe. The effect transcends regional boundaries as the global commodity markets has become highly integrated thus, any change in the prices of food commodity in the global markets take toll on the domestic food commodity markets. It implies that the bioenergy quest in one country can significantly affect the food security in other countries. Also, as the prices of oil continue to rise, food and energy importing nations will face a redoubled balance-of-payment pressures [36].

It is however pertinent to state that from an overall perspective, there is sufficient food for the world to feed. The problem lies in ensuring global access to food. The extent of impact of demand for biofuel product will vary from region to region depending on local consumer’s dietary habits [37]. For instance, the type of food crops used for bioenergy, such as cassava, sorghum, palm oil, soy beans, may constitute 40 percent of a local diet in a region, yet it may be 80 percent in another locality. On the whole, from food security perspective, biofuel development may represent both challenge and opportunity for the four dimensions of food security – availability, access, stability and utilization [35], [36]. In this regard it is meaningful to consider the effect of the rising biofuel demand based on these food security pillars.

3.3.1. Availability

This refers to physical availability of food which addresses the “supply side” of food security and is determined by the level of food production, stock levels and net trade [38]. Physical availability of food could be compromised by rapid growth of biofuel production in the sense that land and water and other resources for production are channelled away from food crop production to energy crop production [35], [39]. Also, rising biofuels production may imply that farmers have to choose between growing food and biofuel crops. But farmers are more likely to choose biofuel crops with higher profits; this could limit food crops cultivation to smaller area with consequent reduced yields. Thus, reduced supply of food crops may trigger hike in price of food crops if the cost of importing foods are high. There has also been the debate that the production of biofuel at commercial scale level widen social margin, increase landlessness and reduced the ability of the poor to access to productive land [40].

However, the extent of potential competition for biomass for food and fuel use will depend on a number of factors; farming practices, crop selection, agricultural yields and the development of new technologies for next-generation biofuel [36]. As second-generation technologies based on lignocellulosic feedstock become commercially viable, negative impact of land and resource competition on food availability may be reduced [41]. Also, food supply of food may be positively impacted if the growing biofuel market result in new investments in agricultural research, development of infrastructure and increased production that could lead to cheaper food and energy prices in remote rural areas [35].

3.3.2. Access

Having access to food means to have both economic and physical access to food. This implies that, even when food is sufficiently available at both the national or international level, ability of the individual household to access or possess it is not yet. Therefore, for there to be access to food, households must have the ability to economically access food or have sufficient purchasing power or access to sufficient resources [36], [39]. Although, agriculture can be revitalized creating new employment and boosting energy access [35], [36], bioenergy developments can impact on the low-income populations such that food prices rise faster than spendable incomes, thereby reducing their purchasing power and increasing food insecurity in the process. The growing biofuel production at commercial scale may reduce the ability of the local households to economic access food by limiting their purchasing power and crippling the disposable income to spend on food [39].

It is anticipated that global food commodity prices will surge in the short to medium-term due to the growing biofuels production. There has been price increment of major food/energy crops in the past involving, sugar, corn, rapeseed oil, palm oil, and soybean. Besides the raising prices of these common energy crops, growing demand for might result in surge in the prices of other basic foods, like cereals, that constitute the large percentage of the least food secured communities daily food intake. The result is that, the possible profit made by producers form higher prices of commodity is offset by the negative welfare effects on consumers, thereby compromising their purchasing power. This was the case in 2006 and early 2007, as the growing demand for corn as feedstock for production of biofuel (ethanol) in the US reduced exports, pressured prices, and threatening access to food for lower income population in Mexico [39]. Therefore, the primary factors determining level of food security for the majority of poor people are their level of income and the cost of food items [36].

3.3.3. Utilization

Utilization generally refers to the way the individual body system makes use of the various nutrients in the food. It refers to peoples' ability to utilize or absorb food nutrients. Adequate energy and nutrient intake results from good feeding practices, food preparation, and the dietary diversity as well as intra-household distribution of food [35], [38]. It is closely linked with health and nutrition factors, such as access to clean water, medical services and sanitation. It also includes food processing practices, such as preparation, storage which may lead to nutrient loss, or other local practices which may negatively affect the consumption of sufficient nutritious food [39], [42].

If bioenergy crop production competes food for water supplies, there could be risk of less water availability for household use, thereby threatening the health status of households and consequently, their food security status. Also, as women spend more time on biofuel refinery, less time is devoted to child care and food preparation and food preparation a situation that could compromise utilization [39], [40]. On the other hand, if modern bioenergy replaces CO_2 emitting energy sources or improves energy services availability, it could make cooking both cheaper and cleaner, with positive implications for food utilization [39].

3.3.4. Stability

Stability exists only if the other three dimensions are stable over time. So regardless of whether you have adequate access to food today, if you still experience periodic inadequate food access that could compromise your nutritional status, you are considered food insecure [38]. In this case, it may be helpful to distinguish between chronic and transitory food insecurity. Chronic food insecurity arises when the minimum food need cannot be met over a long term or lasting for at least six months consecutively. Transitory food insecurity on the other hand, is only a temporary inability to meet the need for minimum food intake. Usually, in this case, there will be some indications of ability to recover [35], [39]. Stability may be affected by rising food prices, unemployment, extreme weather conditions, civil conflicts or political instability, [38], [39].

If local food production is reduced as a result of diversion of factors of production from food to biofuels by farmers, and thereby increasing the dependence of local households on imported food, such food may be subject to more or less variability, and certainty of supply and price, again affecting the stability of food security. Also, mono-cropping can expose the crops to weather effects as well as pest and diseases that may affect the local household income consequently affecting stability [40]. Also, growth in biofuels production rate could affect stability of food supplies as price volatility of petroleum products is more directly transmitted to the agricultural product [39]. These impacts are even worse for food deficit developing countries with high prices of imported foods, and as price transmission increases between global and national markets with the forces of globalization [36].

Overall, the nature of impacts on the four dimensions of food security vary. While the food security level of some people may be strengthened, it will weaken for others. The exact nature of the effect will depend on the socio-economic structure of the society in question, as well as on the commodities whose prices increase and the relative income of the farmers that produce these commodities [36].

4. Mitigating the Impact of Bioenergy Development

A successful resolution of these challenging issues requires the goodwill and commitment of intra and international community to work together. To reverse these trends to what may be considered a sustainable development pathway, a wide range of major transitions action paths have been identified.

4.1. Zoning of Food and Bioenergy Production Areas

One useful Policy initiatives would be the zoning of bioenergy and food production areas in the country. Such zoning should be established on the basis of relative advantage based on the cost benefit analysis of different land uses [43]. This has been practiced in Brazil when the rate of sugarcane production for biofuel raised concerns on its impact on land use. The government adopted the zoning policy to restrict the production to identified suitable area [44].

While it is important to identify land area that is most suitable for bioenergy crops production and the refining thereof [45], zoning will only be helpful in achieving the objectives of food and energy security if implementation is adequately executed and the zones are respected by the policy and decision makers [43]. Nigeria like many other developing countries has good policies and laws, but frequently fails in their implementation, due to a number of factors including inadequate funding, corruption and other administrative problems. To make bioenergy zoning and monitoring work, there will be need for development of tailored policies and establishment of institution that will facilitate the implementation to prevent or as the case may be, reduce incidence of encroachment. Overall, there must be provision for proper financing.

4.2. Improving Rural Infrastructure for National Market Integration

Food insecurity will naturally be more prevalent in some region than the other. The food trade across these regions is a problem mainly due to poor infrastructure, which continues to ravage Nigeria's agricultural development. The region where food insecurity is wider spread is the rural areas where subsistent farming is practiced. It is common in Nigeria that different regions are known for the kind of crops they cultivate, for instance south-western Nigeria is known for production of cacao and cola-nut, southeast for rubber and oil palm, north for maize and groundnut [43]. So for a subsistence farmer who cultivates cacao in the rural south-west, he may not have easy access to maize or groundnut from the north or oil palm from the south-east due to poor road network or transportation. Studies have shown that infrastructure constraints are responsible for majority of the food insecurity challenges with transportation a prime.

Nevertheless, in recent years Nigeria has been committed to investment in infrastructural development with the establishment of the Nigeria Infrastructure Fund (NIF). NIF focuses on improving power generation, agriculture, transportation, access to water resources, healthcare and housing amongst others [46]. However, more than the provision of fund, conscious effort must be exerted to ensure proper implementation of the projects especially in the provision of access road networks to agricultural land areas to facilitate transportation of crops. This way, there will be better access to crops (which will otherwise be become rotten on the farm lands since there is poor access to market) for food and energy production.

4.3. Reducing Barriers to Cross-Border Trade in Food Market

Improving the food markets access will impact food prices as well as the competitiveness of bioenergy. In the developing countries, farmer's food security is best protected through subsistence farming. Usually, smallholder farmers will sell their farm products during harvest since they often lack storage facilities. Thus, they get low returns for their products. This is because the rural farmers are often desperate for cash to meet other needs such as children education and health needs. This situation makes it easy for rural farmers to be cheated by dishonest traders [43].

Reducing cross-border trade will increase regional trade and potentially expand the food market size, stimulate agricultural growth in surplus regions, and improve accessibility in food-deficit ones. Also, ease of regional trade in food products can help balance price volatility of a region [47] in this case, national food security can be ensured by increase in food supplies in regions where there is a shortfall in domestic production [43]. By limiting the factors causing challenges to cross-border trade with global markets, Nigeria can overcome the problems of food insecurity. For an instance, Nigeria rely heavily on Thailand for rice and wheat importation because, it's cheaper than those produced locally. In this case, Nigeria could take comparative advantage of producing bioenergy at relatively lower costs and export to Thailand and using the returns to import rice and other food items that seem cheaper to import. Invariably, food security does not have to come from food self-sufficiency. There will be need for strong and carefully developed bilateral agreement that ensures mutual benefit between Nigeria and the partner country.

4.4. Increase Agricultural Productivity in a Sustainable Manner

Bioenergy is being developed as drivers to control greenhouse gas emissions, boost energy security, and support agriculture. Sustainable technologies and practices can have substantial benefits for the rural poor. For instance, technologies that aid efficient conversion of cellulosic material into bioenergy can help defuse the global demand for traditional food supplies. Although, the importance of organic agriculture to avoid environmental consequences cannot be over emphasized, however, there is doubt on whether organic farming could significantly meet the global demand for food and energy. For instance, Malaysia and Indonesia, which together form the largest producers of biodiesel behind the EU, produce palm oil at about 4 tons per hectare, but the yield could be increased to 6 tons per hectare with available technology [43].

A nation's food security is rested heavily on its agricultural practices [48]. Nigeria is producing below agronomic recommendations because 90 % of agriculture is carried out with hand tools, 7 % with animal-drawn tools while only 3 % is technologically powered. Thus, even with over 70 % of Nigerian engaged in agriculture, food security is a mirage [49]. Nigeria must create enabling environment for mechanized agriculture to thrive and develop policies that will encourage investment in new technologies that promote improved productivity.

4.5. Use of Second and Third-Generation Technologies

Nigeria can exploit the second-generation technologies for bioenergy production to the advantage of the society. Because of the sensitive nature of producing bioenergy from food crops and land acquisition, interest is now growing in the adoption of bioenergy production from second and third-generation technologies. Chakravorty et al. [50] projected that, with first-generation biofuels, the prices of corn and oil seed are likely to rise by 65–75 %, by 2020.

But if the more advanced second-generation biofuels are fully developed, these prices will only rise by 45–50 % [50]. It is possible that wood, straw and even household waste could possibly be economically converted into bioethanol through second generation technology. Karp and Richter [51] have argued that the production of biofuel from high-input food crops needs to be phased out and be replaced with crop residues and low-input perennial crops, which will have multiple environmental benefits [51].

Researches by various scholars have identified a number of second and third-generation bioenergy production options. Second-generation technology for biofuel production from forest and crop residues, energy crops, municipal and construction waste can significantly reduce net emission of carbon, boost energy efficiency and potentially reducing the impacts of dependence on first-generation biofuels [52]. Interest is also growing in microalgae as an ideal third-generation feedstock for biofuel owing to their rapid growth rate, CO_2 fixation capacity and high lipids production capacity notwithstanding the fact they do not compete with food or feed crops, and can be produced on non-arable land [53].

Microalgae have great biofuel potential and can be used to generate liquid transportation and heating fuels, such as biodiesel and bioethanol. Microalgae biotechnology can be used for large scale production of biodiesel without adverse effect on food security [53]. One advantage of second-generation technology is that it does not compete directly with food but it needs energy-intensive processes to produce them, and can increase land-use change. Third-generation technology on the other hand, is free from the challenges of food-fuel competition, land-use change, etc., and so can regarded a more viable alternative energy resource [43].

The Nigerian government must make frantic effort in this regard to create adequate awareness to improve public acceptance and promote research and development in second and third-generation technologies.

4.6. Using Abandoned Agricultural and Marginal Land for Bioenergy Agriculture

There are possibilities for producing bioenergy on abandoned degraded agricultural land. Various researches such as Valcu-Lisman, et al. [29], Mehmood, et al. [54] and Liu, et al. [55] have investigated the potential of biofuel production from degraded and marginal lands. In a broad sense, a degraded or marginal land is one limited in its usefulness for any form of production or regulation function. It is important however to assess when a land should be considered marginal or degraded and when it is available for biofuel production [29], [56].

Degraded and marginal land is also defined in terms of their low rainfall and vegetation cover as well as soil quality. Thus, the use of abandoned and marginal lands may not be good enough to produce commercial quantity of bioenergy. Concentrating bioenergy crop production on marginal and abandoned agricultural lands may not be economically viable as less than 8 % of the current global demand for energy can be met [55], [57]. Thus, biofuel production on degraded and marginal lands may require a comprehensive analysis of the costs and benefits relative to the food security objectives [43]. Degraded lands are scattered across Nigeria due to practices such as vegetation burning, over grazing, shortening of fallow period, accelerated erosion and inadequate land conservation know-how. However, despite the poor economic viability, the Nigerian government can do more to put adequate policies and institutions in place to facilitate better use of marginal lands. Different technologies are also available that enable better use of such land.

5. Conclusions

Finally, generic claims that bioenergy production from food crops only benefits food security have to be treated with caution, just as the counter-claims too. As an agrarian state, Nigeria is a major producer of maize, cassava, oil palm and groundnut which also constitutes the chief dietary food crops. Unfortunately, these crops are also considered good energy crops, thus threatening food security.

This study therefore argues that the rapid bioenergy development if not carefully managed can have tremendous adverse consequences on food security since most food crops constitute feedstocks for biofuel production. The impact may transcend national boundaries as commodity market has become globally integrated. To forestall its consequences, the Nigerian government must develop robust policies and ensure enforcement thereof. It is recommended that such policies be targeted at zoning of production areas for food and bioenergy production based on land suitability, improving infrastructure to facilitate regional market integration, reducing cross-border barriers to boost regional trade in food market, increase agricultural productivity through sustainable technologies and practices, use of second and third-generation technologies to avoid food-fuel completion for resources, and take advantage of marginal and abandoned agricultural land for bioenergy agriculture.

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