A Review of Status and Potentials of Agriculture as a Renewable Energy Source in Climate Change Mitigation in Nigeria

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Abstract

The importance of energy to a nation's economic development cannot be overemphasized. However, an increasing production and utilisation of fossil fuels on which Nigeria's industrialization is majorly dependent would contribute to global warming due to emission of greenhouse gases (GHGs). This paper argues that agriculture as a potential bioenergy resource can play an important role in climate change mitigation while enhancing Nigeria's sustainable economic development agenda. The paper through a critical document analysis examined Nigeria's potential to provide biofuels from agriculture and also highlights factors constraining the development of the bioenergy industry. The paper posits that Nigeria can significantly reduce its energy deficit and also contribute to global climate change mitigation efforts if the biomass materials readily available in the country are utilised through the deployment of appropriate technologies. Such engagements will not only promote a clean and healthy environment but also improve the living standard of the citizenry through jobs creation.

Key Words: green house gas emission climate change mitigation, clean energy

1. Introduction

One major component of the greenhouse gases (GHGs) responsible for global warming which has led to changed climate is carbon dioxide (CO2). A prime source of this CO2 emission is fossil fuel combustion. Visible negative impacts of climate change has led to increasing focus on sustaining development by the global community which has seen the need to control carbon emissions within the ambit of a sustainable development agenda. Sustainable development is the process of simultaneously promoting economic development, improving social well-being and ensuring a healthy environment. Sustainable development has been greatly inhibited in Africa as a result of absence/inadequate energy sources. African governments in recent times are beginning to mainstream climate change response strategies into national development plans especially those that seek to address energy issues.

The paper's major aim is to review the literature critically and provide a discourse on the potential of agriculture as a source of renewable energy and one through which climate change can be mitigated to a large extent while also addressing Nigeria's energy deficit. The specific objectives of the paper include emphasizing the impacts of climate change and the problems associated with the use of fossil fuels. The paper also seeks to examine the Nigerian government efforts to mainstream climate change management strategies into policies and regulations that enhance the utilization of biomass for

production of biofuels. The paper employed a critical document analysis of numerous published articles that included publicly available energy and environmental policy documents of the government of Nigeria.

The organization of the paper is such that the next section discusses the role of energy in the economy and the problems associated with the usage of fossil fuels, followed by a review of climate change impacts on society and systems. This is followed by sections that present the potential of agriculture as a source of bioenergy and highlights the implication of a growing bioenergy market for the country's food security status as well as policies and challenges constraining bioenergy development in Nigeria. The paper concludes by drawing on salient points gathered from the discourse to make recommendations.

to have quadrupled and has led to a 16-fold increase in energy consumption (Hoffert & Caldeira, 2004). Apparently, a global co-integration movement between population growth and energy consumption has been observed (Ness, 2004). Adequate and reliable energy supply is critical to improving the living standard and socioeconomic status of the world's growing population.

The importance of energy in driving the economy cannot be overemphasized as it is needed in every sector for effective and efficient operations. One major sector in many economies especially those of Africa that relies heavily on energy is the agriculture sector. Reportedly, about 30% of world's total energy is consumed by food systems, an indication that energy is very vital to achieving food security and better nutrition and more so, the

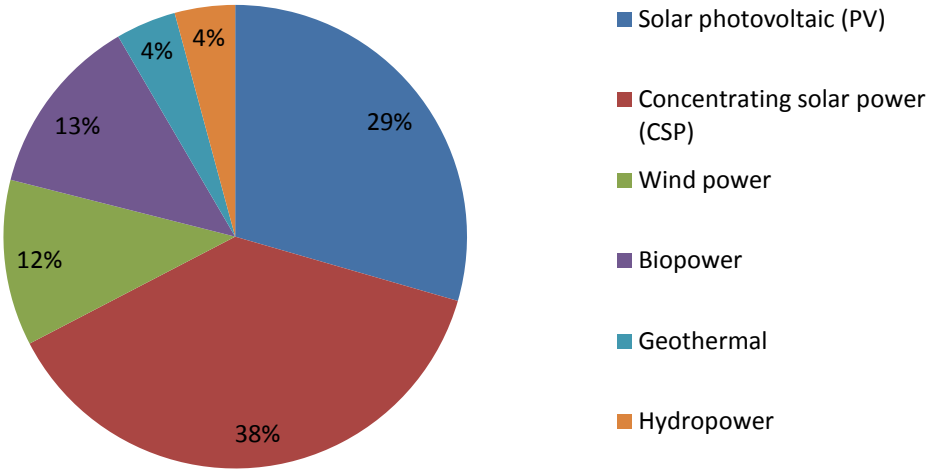

Figure 1. Global growth rates of renewable energy technology (2012-2013)

Source: (REN21, 2014).

The role of energy in economic development

Energy is critical to the growth of every economy. It is needed to boost every country's industrialization process. Global increasing energy demand has been attributed to a growing global urban population (Ruti & De Felice, 2013). The human population is noted

availability and affordability of energy affects agricultural production and food prices (FAO, 2015). Inarguably, the agriculture sector is strongly linked to the energy sector as energy is utilized through farm mechanization, petrochemicals (e.g. fertilizers and pesticides) and in transportation of farm inputs and

products (Buttel & Youngberg, 1982). In addition, the link between fossil fuel based energy production and climate change is well established (Cruz et al., 2013; Hoffert & Caldeira, 2004; Rosenfeld, Mcauliffe, & Wilson, 2004) as the emissions arising from energy production and utilisation are also the major contributory factors to climate change. Consequently, climate change has been a major driver for the shift towards promoting renewable energy in recent years (Goldemberg, 2004). The last decade has seen a remarkable increase in global renewable energy usage as shown in Figure 1

Furthermore, the epileptic power supply in Nigeria and the increasing challenges posed by a growing population and climate change provides an opportunity for Nigeria to fully exploit numerous options to provide energy to boost economic growth through industrialisation. This paper advocates for the use of bioenergy as an alternative and/or supplementary energy source to the use of fossil fuels in Nigeria since there is a vast amount of biomass reserves available for use in the country as shown in Table 1. However, bioenergy as a means of supplementing and boosting energy supply to meet energy needs

Table 1. Nigeria's biomass reserves/capacity as at December 2013

Biomass	Reserves	Production	Domestic utilization (Natural units)
Fuel wood	11 million hectares of forest and woodland	0.120 million tonnes/day	0.120 million tonnes/day
Animal waste	245 million assorted animals	0.781 million tonnes/day	-
Municipal waste	30 million tonnes/year	-	-
Energy crops and agriculture residue	72 million hectares of agriculture land	0.256 million tonnes/day	-

Source: Energy Commission of Nigeria (2014:2), Sambo (2009:5).

In addition, the renewable energy industry is a significant employer of labour as it reportedly provided jobs to about 5.7 million people directly or indirectly around the world in 2012 (International Renewable Energy Agency [IRENA], 2013). However, it is noted that the bulk of employment was concentrated in the European Union, the United States, China, Brazil and India. It is therefore, glaring that the African continent is yet to tap significantly into its renewable energy potential to boost its development and light up the continent and lives.

has greater implications for developing countries than developed economies where renewable sources serve as means of diversifying national energy supply to achieve the concept of sustainable development (Amigun, Sigamoney, & von Blottnitz, 2008).

An overview of climate change impacts

Climate change is the change in weather conditions which persists over an extended period (Gosain & Rao, 2003). It has been projected that climate change will cause Nigeria to witness a possible sea level rise of

1m by 2050 from 1990 levels (Federal Government of Nigeria [FGN], 2010). Atmospheric GHGs naturally warm the earth at a level suitable for habitation but increasing concentrations of these GHGs (water vapor, carbon dioxide, methane, nitrous oxide and chlorofluorocarbons) from anthropogenic activities have resulted in enhanced natural global warming (IPCC, 2007a). The impacts of climate change include high precipitation, flooding, drought, extreme temperatures and heat waves, hailstorm, wildfires, and sea level rise (IPCC, 1998) which in turn affects humans and the environment. Hydrologic extremes of drought and flood can greatly impact human health, agriculture, energy production, infrastructure and recreation. For instance, drought can cause food shortage and may result in unavailability of drinking water and more atmospheric water vapor could lead to increased precipitations that result in flooding.

Climate change compromises agricultural production, especially in smallholder systems with little adaptive capacity, as is the case in many parts of Africa (Brown & Funk, 2008; Müller, Cramer, Hare, & Lotze-Campen, 2011). Agriculture which is the mainstay of Africa rural economy is characterized by small-scale subsistence farming with water resources considered too low to meet the continent's water demand for drinking, farming and other activities. It is projected that by 2080 as much as 240 million people could be undernourished as Africa's agriculture will be greatly affected by changing climate and about 350-600 million people will face water stress (Pan African Climate Justice Alliance [PACJA], 2009). In Nigeria, agriculture is a source of livelihood for more than 70% of the population and therefore the adverse impacts of climate change could have significant implications for the country's economy (Federal Government of Nigeria [FGN], 2010). Developing countries are more vulnerable to climate change due to their limited capacity to adapt to climate change impacts as a result of their locations, socioeconomic status, demographic and policy trends (Morton, 2007). Obviously, the impact of climate change on crops, forestry and water would affect bioenergy development.

Equally important is that climate change affects other aspects of the economy such as infrastructure, houses and properties (Intergovernmental Panel on Climate Change [IPCC], 2007a). Energy installations can be vulnerable to climate-related events such as heat waves storms, flooding and drought. For instance the lack and/or shortage of water can result in a shortage of power from hydropower stations and inadequate thermoelectric cooling water during thermoelectric power generation; offshore oil platforms can be destroyed during storms while facilities along coastlines can be threatened by floods from sea level rise; the rhythm of fuel production and transportation of fossil resources can be disrupted by change in temperature and precipitation (Miller, 2013). For example, Nigeria has witness reduced water flow from the River Niger and its tributaries as a result of changing weather conditions and other climate-related impacts (Iwayemi, 2008) and this has reduced the capacity of the country's three major hydropower stations (Kainji, Jebba and Shiroro dams) in recent years. In addition, rising temperature could lead to increasing wildfire incidences that can destroy houses and extreme heat can cause petroleum pipelines to burst. Without doubt, climate parameters such as temperature change which creates heating and cooling needs in homes and industries, partly determines electricity demand (LePoire, 2013). Consequently, there is need to increase access to modern efficient energy sources while mitigating climate change through energy sources producing less carbon emissions. According to a REN21 (2014) report, renewable energy accounted for more than 19% of global energy.

Potential of agriculture as a renewable energy source

Nigeria is largely regarded as an agrarian society as agriculture is a dominant economic activity in the country. More than 75% of the

country's land is arable and out of which about 45% is cultivated (Ayodele, Obafemi, & Ebong, 2013). It is therefore posited that Nigeria has adequate arable land with potential for improved productivity. Unfortunately, the Nigerian agricultural sector has been beset with many challenges that include low productivity, weak institutions, market inaccessibility, inadequate financing and lack of electricity. In Nigeria, just about 10% of rural households and 40% of the total population has access to electricity while the country is generating less than 30% of its installed generating capacity due to numerous challenges (Shaaban & Petinrin, 2014). Yet there are indications that the future energy needs of Nigeria will be driven by a combination of factors that include population growth, urbanization and industrialization quest. It becomes clear that Nigeria's energy supply is insufficient in driving the economy including the agriculture sector and as such, the sector needs to look inward and tap into its potential as a source of energy. Agreed, there has been a global debate on the potential of the agricultural sector as a significant energy producer in contrast to its traditional role of energy user.

Evidently, the agriculture sector is a significant user of energy; energy is used in agricultural activities directly (e.g. fuel and electricity) or indirectly in the form of fertilizers and pesticides (Beckman, Borchers, & Jones, 2013). However, considerable amounts of GHGs are emitted into the atmosphere during agricultural activities directly or indirectly. The major direct sources of emissions include the use of nitrogenous fertilizers, animal dung, rice farms and biomass burning etc. while indirect sources include production of fertilizers and pesticides, fuel used in farm machinery and transportation of farm inputs and products (Lawler et al., 2013). Studying the nexus between climate change, energy and agriculture reveals the need to reduce the dependence of agri-food value chain on fossil fuels by utilizing cleaner energy forms like bioenergy. Such strategy must however be based on sustainable biomass supply that will not endanger food security (availability, accessibility, stability and utilization), protects the environment and improve the nation's economy. Improving agriculture to meet future food requirements especially in developing economies like Nigeria means that cultivable agricultural land area could be doubled to increase production or greater investment can be made on farm management and technology applied on current agricultural land (Müller, 2009).

It is important to note that the oldest form of renewable energy ever exploited by humanity is biomass energy, and mostly in the form of wood which is inefficient and detrimental to human health and the environment. More than 70% of the people living in the rural areas in Nigeria are using fuelwood and the country uses more than 50 million tonnes of fuel wood annually (Oyedepo, 2014). This situation has contributed to both deforestation and desertification that are going on at the rate of 350,000ha/annum while reforestation is only about 10% of the ongoing deforestation rate (Oyedepo, 2014). The deforestation rate in Nigeria is reported to be at 55.7% and is about the highest in the world (Ngumah, Ogbulie, Orji, & Amadi, 2013). Deforestation and desertification hinders the ability of the earth's forest and vegetation to act as carbon sink in mitigating global warming (Akinbami, Ilori, Oyebisi, Akinwumi, & Adeoti, 2001). Reportedly, more than 2.6 billion people are dependent on traditional form of biomass energy for domestic activities (REN21, 2014).

Bioenergy is the conversion of biomass energy into other useful forms of energy for domestic and industrial activities. Biomass refers to all organic material originating from plants, trees and crops that can collect and store the sun's energy through photosynthesis (Kammen, 2004). About 60% of total energy consumed in Africa is reported to come from biomass and it is projected that by 2030, about 823 million people in Africa will depend on biomass

(Ackom & Ertel, 2005). Biomass can be transformed into various forms of biofuels as further explained.

Biofuels and biogas

Biofuels are produced from biomass and could be in the form of liquid, gaseous or solid state which can be used for cooking, heating, electricity generation and as fuels for transport (FAO, 2015). Biofuels are made from biomass through biochemical (fermentation and anaerobic digestion) or thermochemical processes such as gasification, pyrolysis, and liquefaction (Amigun et al., 2008). Biofuels include wood-based methanol and biodiesel from soy, rapeseed oil and switch grass as well as corn and sugarcane-based ethanol known as bio-ethanol derived from fermentation of organic, sugar-rich substrates into alcohol for use in vehicles and machinery (Nehrenheim, 2014). Few commercial bioethanol plants have been established in African countries such as South Africa, Swaziland, Malawi, Zimbabwe, Mauritius, Ethiopia and Kenya (Amigun et al., 2008). Biofuels have been categorized as first generation which uses parts of plants containing sugar, starch or oil, second generation (uses entire plant parts by breaking up cellulose) and third generation biofuels which use algae under controlled environment (Fekete 2013). Biodiesel is a class of biofuels having about 38% higher energy than ethanol and is made from oil crops such as canola, palm oil, rapeseed, sunflower, coconut and soybeans (Fekete, 2013). Biodiesel is meant for diesel engines. As at 2013, global annual ethanol production increased from 28.5 billion litres in 2004 to 87.2 billion litres in 2013 while annual biodiesel production increased from 2.4 billion litres to 26.3 billion litres in same period (REN21, 2014). Biodiesel demand in Nigeria is projected to increase to 900 million litres in 2020 from the 480 million litres demanded as at 2007 (Samuel & Adekomaya, 2012).

Biogas is formed when organic materials are degraded in the absence of oxygen. Biogas can be used for cooking, heating, lighting and numerous industrial electronic tools and operations (Itodo, Agyo, & Yusuf, 2007). A thoroughly cleaned up biogas can be compressed for use in internal combustion engines. It is a mixture of methane (60-70%) carbon dioxide (30-40%) and traces of hydrogen sulphide, ammonia, and carbon monoxide (Ngumah et al., 2013; Usman & Ekwenchi, 2013). Biogas technology has been in existence since 1850's and its two main products are biogas (energy) and biofertilizer which is the residual effluent (Ngumah et al., 2013; Usman & Ekwenchi, 2013). The biofertilizer is made up of lignin, cellulose fibres and remnants of anaerobic microorganisms. Biofertilizers are eco-friendly and do not contain toxic materials. They are considered better than chemical fertilizers as they enrich the soil fertility without any harmful effects on the environment (Umeghalu, Chukwuma, Okonkwo, & Umeh, 2012). Biofertilizers save cost associated with synthetic fertilizers and soil conditioners (Ojolo, Oke, Animasahun, & Adesuyi, 2007). In order to avoid build-up at sites, produced biofertilizer can be package in bags and sold to nearby or far away farms or even given away freely. Biogas digester technology has been widely adopted in many developed and developing countries including the United States of America, China, India, Brazil, Germany, Austria, Denmark, Italy, Switzerland and France (Chasnyk, Sołowski, & Shkarupa, 2015). However, the use of biogas is still limited in sub-Saharan African (SSA) countries including Nigeria except for countries like Tanzania, Burundi, Kenya and Botswana (Akinbami et al., 2001). Nigeria's potential for biogas production has been well researched and as Ngumah et al. (2013) pointed out, Nigeria is capable of producing 25.53 billion m3 of biogas annually from various organic wastes. It is opined in another study that Nigeria has a potential of generating 6.8million m3 of biogas per day from fresh animal waste (Ishola, Brandberg, Sanni, & Taherzadeh,

2013). Waste could be generated from producing biodiesel from oil crops like

Table 2.Various materials used as feedstock for biodigesters

Category of waste	Examples of materials
Agricultural	Animal dung, poultry manure, crop residues, aquatic weeds, straw, grasses, slaughter waste, etc
Household	Kitchen wastes, sweeping wastes, packaging wastes, solid waste and sewage, etc
Industrial wastes	Pulp and paper residues, hospital wastes, chemical wastes, metals, plastics, textiles, etc.

Source: Akinbami et al. (2001).

seen in Table 2. The various feedstocks that can be fed to biodigesters to produce bioenergy are discussed further in the following section..

Energy crops, agricultural residues and municipal wastes

Increasing global support for bioenergy from agricultural crops and residues has led to expansive production of energy crops worldwide as strategies towards mitigating climate change (Farinas, 2015). In some instances, this increment has come at the expense of land allocated to other crops and this has been pointed out as partly responsible for the higher prices of food crops (Beckman et al., 2013; Fekete, 2013). The Nigerian government plans to produce biodiesel from energy crops such as cassava, maize and other feedstocks like used cooking oil, sunflower etc (Mangoyana, 2009). However, the use of cassava for bioenergy in Nigeria is viewed as a very expensive venture as it requires much energy and enzymatic hydrolysis due to its starchy nature (Ishola et al., 2013). A greater concern on the use of cassava is that it is a staple food for more than 70% of Nigerian citizens and as such, it is feared that such venture could drive up the price of cassava beyond the reach of the poor in a country where majority of the population live on less than $2 a day (Amigun et al., 2008). Nigeria also has a great potential of

2005; Baroi, Yanful, Rahman, & Bergougnou, 2009).

The use of energy crops has been preferred for two major reasons that bother around technological and environmental factors and as explained, energy crops provide a reliable supply of electricity and posses more flexibility in technology and adaptability in addition to contributing to earth's forest cover that help to mitigate the effects of global warming (Collins, 1999). Nonetheless, there are diverse challenges associated with the use of energy crops as would be discussed later. It is however, perceived that bioenergy would be more beneficial and sustainable to Africa and especially in the Nigerian context if non-food crops (agricultural residues and municipal wastes) are used as feedstock.

There is an abundance of agricultural waste in Nigeria and this is partly attributed to poor technology employed in agricultural activities (Oyedepo, 2014). This waste can serve as feeders for biodigesters or as combustible feedstock for power plants. In addition, Nigeria's mega cities and towns generate enormous amount of waste that can be used for biomass power generation. For instance, methane through the use of appropriate technologies can be captured from landfill sites and converted into natural gas that could be used for cooking and generating electricity etc. (Beck & Martinot, 2004; Davidson et al., 2006; Freire, 2013). The density of solid waste in

Nigeria as observed, ranges from 280 to 370 kg/m3 and the per capita waste generation is about 0.44 to 0.66 kg/m3 per day (Ogwueleka, 2009). Another study (Abila, 2014), estimated the waste generated in Nigeria as about 0.49-0.58kg per capita and about 86 million metric tonnes daily by the entire population.

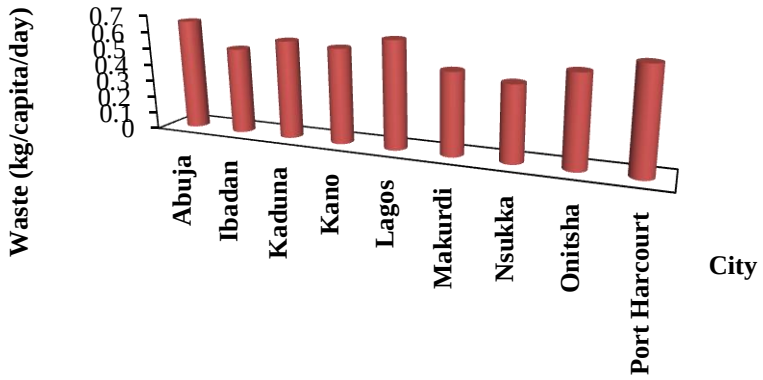

Figure 2. Amount of waste produced in some Nigerian major cities

Source: Ogwueleka (2009)

which is often done indiscriminately on the streets causing aesthetic pollution and breeding grounds for pathogens (Orisakwe, 2011; Suberu, Mokhtar, & Bashir, 2012). This is despite the existence of a National Environmental Standards and Regulation Enforcement Agency (NESREA) established in 2007 (Ladan, 2012) to enforce the National Policy on the Environment, 1989 (Kankara, 2013). The NESREA has developed and published 24 environmental management regulations since inception and among which is the National Environmental (Sanitation and Wastes Control) Regulations, 2009. S. I. No. 28 that deals with the legal framework on the adoption of sustainable eco-friendly practices in environmental sanitation and waste management to minimize pollution. Illustratively, the amount of waste generated daily in some major cities is shown in Figure 2. It is seen that Abuja, Lagos and Port Harcourt cities associated with large influx of urban dwellers tend to generate higher amount of wastes. Persisting environmental pollution from industries show that there is poor enforcement of environmental protection laws in Nigeria (Adeyemo, 2003).

The neglect or inefficient management of generated wastes contributes to global warming because GHGs are also emitted from dumped wastes. However, GHGs are well-known sources of renewable energy that can be utilized. In this regard, the construction of biodigesters at dumpsites to produce compressed biogas is very much touted. The generation of biogas from such provides an opportunity to boost the country's energy supply, more importantly for decentralization of electricity production for remote communities or small isolated areas that are disconnected from the national power grids (Abila, 2014; Oyedepo, 2012). Other benefits associated with the conversion of waste to energy include the reduction of waste volume that end up in landfills thereby reducing carbon emissions, reduced cost of producing recycled materials, job creation for waste management workers and the promotion of a clean and healthy environment. More so, the promotion of

bioenergy usage will potentially limit deforestation and therefore boost climate change mitigation efforts (Lawler et al., 2013).

Overview of Nigeria energy policies

Nigeria suffers from chronic energy deficit, mostly felt in the form of inadequate electricity supply for domestic and economic activities and which is widely perceived as majorly responsible for the country's poor economy (Oladokun & Asemota, 2015). Apparently, with the global evidence of climate change and its impacts, government has seen the need to rise to the challenge of meeting energy needs for industrialization and in this realization, renewable energy sources are regarded as vital to solving the country's energy problems. Nigeria has a National Energy Policy (NEP) formulated in 2003 and which was reviewed in 2013 to address current needs of the energy sector(Energy Commission of Nigeria [ECN], 2014). More so, a Renewable Energy Master Plan (REMP) which lays out Nigeria's vision and roadmap for increasing the role of renewable energy was later formulated in 2005 by the Energy Commission of Nigeria (ECN), with the support of the United Nations Development Programme (UNDP) to provide a strategy towards reducing emission and addressing the challenges of transitioning to clean, reliable, secure and competitive energy supply (Shaaban & Petinrin, 2014). Among the energy supply mix targets, the REMP sets out to achieve the generation of 100MW of electricity from biomass in the medium-term and 800MW in the long-term (Sambo, 2009). In addition, the REMP offers incentives for investment in renewable energy projects through a range of fiscal and market policies that include waivers on import duties for renewable energy technologies, tax relief/holiday and preferential loan opportunities tax holiday for bioenergy companies, import duty waiver for farm equipments and industrial-process chemicals and the strengthening of the Nigerian Agricultural Insurance Corporation (NAIC) to provide cover for all risk associated with biofuel feedstock (Ohimain, 2013).

Furthermore, a National Energy Master Plan (NEMP) was formulated in 2007 to enhance the implementation of the national energy policy goals through specific framework and implementation strategies. The NEMP was also reviewed in 2014 to reflect the objectives of the revised NEP (ECN, 2014). The NEMP specifically addresses the production and utilization of biomass energy in that it makes some important recommendations among which include reforestation, the development of local capacity and manpower for effective deployment of bioenergy technologies, provision of fiscal incentives to encourage investments in bioenergy technologies and establishment of rules and regulations to boost the synergy between the agricultural sector and the biofuels industry. The NEMP also points out the need to maintain a sustainable development of bioenergy products to avoid unhealthy competition for land among food crops, energy crops and biodiversity conservation. Also, included in the NEMP bioenergy policies is a waste management framework that will enhance the conversion of waste to energy. To discourage deforestation, the NEMP seeks to de-emphasize the use of wood as fuel and promote the use of alternative biomass sources that include forestry and agricultural residues, municipal and industrial wastes and the production of energy crops such as jatropha, aquatic weeds, sugarcane, cassava, castor oil and sunflower (Mohammed, Mustafa, Bashir, & Mokhtar, 2013). The NEMP also seeks to promote the use of biofuels for vehicles. Bioethanol can be blended to up to about 30% with fossil gasoline just as biodiesel can be blended with diesel and it was on this basis (Ishola et al., 2013) that the Nigerian government in 2007 launched a biofuel program to avail the domestic market a gasoline blended with 10% ethanol (E10). However, not much commercial progress has been made in this regard (Ishola et al., 2013).

In addition, the Nigerian government established a Renewable Energy Division within the Nigeria National Petroleum Company (NNPC) in August 2005 (Samuel & Adekomaya, 2012) tasked with sensitizing the public on the cultivation of energy crops for biofuel and initiating a framework for the importation and production of biofuel. In as much as biofuel production integrates the agricultural and energy sectors, the utilization of bioenergy has been encumbered with numerous constraints.

Challenges constraining bioenergy development in Nigeria and the way forward

The numerous constraints to bioenergy utilization in Nigeria that have been identified include firstly, issues of public perception of biofuels. For instance, it is claimed that the production of biofuels use up more fossil fuel than they produce as biofuels, even though they release less carbon monoxide and sulfur dioxide (Pimentel 2001). More so, it is feared that the intensive cultivation of bioenergy crops as some believed, would lead to reduction of organic matter content of soil, higher erosion, loss of biodiversity and higher net carbon emission than fossil fuel combustion as a result of the emissions associated with land clearings (Lange, 2013; Mangoyana, 2009). Secondly, it is perceived that energy crops require more land area and significant amount of water to grow and this would be at the expense of food production (Lawler et al., 2013). Since 2007, the increasing use of biofuel has been associated with spiraling prices of food as a result of increased competition for land, labour and capital between food crops and energy production (Ishola et al., 2013; Mangoyana, 2009). Thus, the fear of food shortage and spiralling food prices that may result from such competition has somewhat affected the enthusiasm and desire of the public to embrace government bioenergy policies (Aliyu et al., 2015, Samuel & Adekomaya, 2012).

Thirdly, the cost implication in terms of capital and land space requirement in setting up biogas digesters is considered high in a country like Nigeria where many are poor. The capital outlay of bioenergy infrastructure could be prohibitive. Reportedly, the estimated average cost of a $10m^3$ biogas plant is about $2800-$4200 and this is considerably high for the average Nigerian citizen/farmer (Aliyu et al., 2015; Iwayemi, 2008). Fourthly, environmental challenges such as poor waste disposal habit among the populace, lack of waste characterization habit, inadequate waste collection equipments, corruption and lousy attitude to work among waste collectors results in inefficient and inadequate accumulation of required waste material for sustainable bioenergy projects (Taiwo, 2009). Apparently, in spite of the plethora of environmental rules and regulations, there has been limited success in bringing environmental pollution to minimal in the country (Echefu & Akpofure, 2002). Fifthly, there is lack of adequate technology and manpower, lack of required technical skills to operate modern bioenergy equipments and machines. Sixthly, the inability of many farmers in the rural areas to own large farm areas that could enable for large cultivation of biofuel crop is a challenge to development of the bioenergy market in Nigeria (Ogaboh, Abam, Agba, & Okoro, 2010). Seventhly, the lack of legal backing for the country's renewable energy policies are seen as partly responsible for the poor enforcement and sustenance of these policies (Sambo, 2009). Lastly, despite a proposed preferential long-term soft loans to be given to large-scale farmers to enhance their production capacity (Samuel & Adekomaya, 2012), there is not much data to show that the rural farmers that produce the bulk of agricultural products are actually receiving adequate incentives as proposed by the government to encourage them cultivate more of the required energy crops. Agreed, biogas technology in Nigeria has not attained the desired level of commercialization despite the available huge biomass resource.

Evidently, Nigeria has a great potential of generating bioenergy from the agriculture sector but the exploitation of this resource is greatly inhibited. Therefore, to fully harness this potential, there is need to boost investment in the agriculture sector as have been witnessed in the production of energy crops (e.g. maize, sugarcane, castor oil, jatropha, etc.) and the energy crops should mostly be cultivated on marginal lands that are considered not fit for agricultural purposes. More so, the use of energy crops for biofuel production would require large dedicated area of such crops to sustain their usage as feedstocks without negatively affecting the supply of such crops for food consumption. In this regard, biotechnologically modified energy crops should be adopted for significant boost of the country's crop production level. Further, the development of bioenergy sources requires a strong working synergy between the energy and agricultural sectors and the waste management regulating agency at the national, state and local levels. With waste management, government especially at the state and local level must take significant practical steps in developing public-private partnerships that can provide suitable and effective solutions to the problem of waste management in the country. There is need for improved funding of sewage systems and a systematic collection of waste to provide input for biodigeters. In addition, the populace needs orientation and sensitization on the importance of characterizing wastes for efficient disposal. Finally, Nigeria must take significant steps to legalize and enforce policies that promote the development of bioenergy, in the context of this paper, biogas, ethanol, methanol and biodiesel.

Conclusion

This paper had set out to explore the potential of the Nigerian agricultural sector in providing bioenergy. It also examined the constraints inhibiting bioenergy development in the country. To this end, the paper explored the nexus between climate change, agriculture and energy, thereby highlighting the need for appropriate measures to respond to the adverse effects of climate change. The paper argued that the utilisation of bioenergy will enhance Nigeria's industrialization process, reduce dependence on fossil fuel and create a strong synergy between the agriculture and energy sectors. It emerged that Nigeria with its huge potential for renewable energy generation from wastes needs strongly institutionalized waste management processes that can incorporate international best practices and also engage the general public in cooperating with waste management regulations. Further, the sensitivity of the agriculture sector to climatic conditions calls for appropriate mitigative and adaptive measures from all stakeholders.

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