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Review

Bioenergy production and food security in Africa

James C. Ogbonna[1]*, Nakao Nomura[2] and Hideki Aoyagi[2]

[1]Department of Microbiology, University of Nigeria, Nsukka, Nigeria.
[2]Faculty of Life and Environmental Sciences, University of Tsukuba, Japan.

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Food and energy insecurities are the two greatest problems in Africa. Per capita energy consumption in Africa is less than 10% of that of United States of America while 18 out of 23 countries where starvation and malnutrition are most severe in the world are in Africa. Although various African governments have been making efforts to boast agricultural productivity, crop yields remain very low. Most governments do not even have accurate statistics on the number, location and types of crops produced by smallholder farmers that produce more than 80% of foods in Africa. This makes it very difficult to plan and implement any government support to the farmers. Sub-Saharan African countries have very high potential for production of different forms of bioenergy because the climatic conditions favour production of many energy crops. The big question has always been whether to produce bioenergy from food crops, especially in Africa with high acute food shortages. Large scale production of bioenergy may lead to competition with food crops for land, labour and other agricultural inputs. However, data from various sources indicate that Africa has abundant and underutilized arable land which can be effectively used for mass production of energy crops. Furthermore, shortage of labour cannot be a problem given the present very high rate of unemployment in most African countries. The benefits of bioenergy production in Africa outweigh the possible adverse effects on food security. Bioenergy production will create demand for, and stabilize the prices for crops, thereby increasing the earning of the farmers. This will in turn, facilitate industrialization in other sectors of economy through provision of affordable, renewable and clean energy. In order to minimize possible negative effects of bioenergy production on food security, land allocation for energy crop production can be regulated. Energy security cannot be separated from food security and the two should be seen as complimentary rather than as competitors.

Key words: Bioenergy production, food security, energy.

INTRODUCTION

In view of the non-renewable nature of fossil fuels and the various environmental problems associated with drilling, distribution and use of fossil fuels, a lot of attention has been focused on renewable energies. Among the various types of renewable energies, bio-energies have very high potentials because the major raw materials can be produced in most ecological zones at will, at all time and in desired quantities. They can be processed into gaseous, liquid and solid forms, thus making them suitable for various industrial, domestic and transportation applications. They are also environmentally friendly in that they are biodegradable and thus do not

*Corresponding author. E-mail: james.ogbonna@unn.edu.ng. Tel: +2348037136810.

Abbreviations: IEA, International Energy Agency; **AGRA,** Alliance for a Green Revolution in Africa; **FAO,** Food and Agriculture Organisation; **GM,** genetically modified; **GDP,** gross domestic product.

constitute major soil or water pollutants while most of them are either carbon neutral or carbon negative. However, there has been a lot of debate on the effects of large scale bioenergy production on food security, especially in Africa where hunger and malnutrition have persisted for decades (Cotula et al., 2008; Jumbe et al., 2009). This paper highlights the current situation of energy and food production in Africa, discusses the interrelationship between energy security and food security, the potentials of bioenergy production in Africa, as well as the possible negative and positive effects of bioenergy production on food security in Africa. A vertical integrated bio-energy production system which can be used to achieve both energy and food securities in rural African communities and thus reduce poverty is proposed.

ENERGY SITUATION IN AFRICA

Africa is a very energy poor continent. Electrification rate in Sub-Sahara Africa is only 30.5% while only 14.2% of those living in rural areas are connected to power grid (WEO, 2011). Furthermore, the International Energy Agency (IEA) estimated that the per capita power consumption in Africa is only 7.7 kWh/capita which is far less than 14.421 kWh/capita in Latin America or 87.216 kWh/capita in the United States of America. Furthermore, only four countries in Africa (Algeria, Nigeria, Libya, and South Africa) have significant amount of fossil fuels (oil, gas or coal). Nigeria, Libya and Algeria oil reserves are estimated to be 37.1×10^9 bbl, 48.5×10^9 bbl and 12.12×10^9 bbl; and at the present rate of production, they are expected to last for only 41, 76 and 22 years, respectively (www.opec.org).

Africa has remained the poorest continent with estimated 265 million malnourished and 273 million people living on less than US$1 per day (APPPB, 2010). According to FAO (2012), 18 out of 23 countries where hunger is most severe in the world are in Africa. Energy availability and costs have an overwhelming influence on national development. No nation can develop without reliable and affordable energy sources. Energy availability determines the type of industries, and the cost of energy has significant effects on the cost of production and distribution of goods and thus the global competetiveness of companies. Energy availability affects not only industrial and agricultural development but also education and training (teaching and research). It is arguable that the lack of access to reliable and affordable energy source is a major problem limiting industrial development in Africa. Many teaching and research literature materials are now in the internet but cannot be accessed by many Africans because of lack of electricity. Many research projects cannot be implemented in many African communities because of lack of reliable and stable power supply. Energy supply also affects production and distribution of many social amenities such as water, and health care delivery. Thus, energy security is pivotal to African development.

The big question is therefore how Africa can achieve energy security at both national and local levels. Important aspects of energy security include availability, reliability and affordability. However, in quest to achieving energy security, the environmental and social implications of various energy sources must also be considered. It is therefore necessary to develop renewable energy alternatives as a means of diversifying their energy sources and export commodities, and reducing environmental pollution and degradation associated with drilling, distribution and use of fossil fuels.

FOOD SECURITY IN AFRICA

Food security simply means a condition where people have guaranteed access to safe and nutritionally balanced food in appropriate quantities over time by production, purchase or both. The four main components of food security include physical availability of food, food access (purchasing power/affordability and social/religious liberty to purchase and eat), food use (knowledge and liberty to eat appropriate quantity and quality of food) and stability of food supply over time. Food security can be at individual, family, group or national level. The ultimate goal of food security is to eliminate hunger and malnutrition.

Food availability in Africa

Starvation has remained endemic in Africa in spite of all the previous “green revolutions” under different names aimed at increasing agricultural productivity in Africa. It is clear that such efforts have not yielded the expected results. One of the major reasons for the shortage of foods in Africa is the very low crop yields. Data from various sources confirm that average yields of various crops in Africa are less than half of the world average and in some crops, less than 20% of the yields in some developed countries (Chaurin et al., 2012; Langyintuo, 2013). In all the agro-ecological zones in Africa, there is still a huge gap between the potential and actual yields of crops (Pingali et al., 2010). Between 1961 and 2009, average cereal yields increased only from about 800 kg/h to about 1,500 kg/h (88% increase) in Africa. However, during the same period, the yields increased from 1250 kg/h to 3500 kg/h (180% increase) in Asia, and from 1,400 kg/h to 4000 kg/h (186% increase) in South America (Jama et al., 2013). By 1961, for example, yields of grains in the United States was already 2 ton/h but more than 50 years later, average yields of grains in Africa is only about 1.5 ton/h, in spite of all the apparent efforts being made by the Governments and different organizations to boast crop production in Africa. Even the slight increase in agriculture production has been mainly due to expansion of cultivated land rather than increase in yields. Yet in some areas, expansion of cultivated land is restricted by land ownership and land tenure systems. The current climate changes will even reduce agricultural productivity in Africa where most farms are rain-fed.

Jane Karuku, the president of Alliance for a Green Revolution in Africa (AGRA) in the Food and Agriculture Organisation (FAO) reported on the state of Agriculture in Africa (AGRA, 2013) enumerating what smallholder farmers in Africa need to boast Agricultural productivity. These include supportive policies, access to better seeds, fertilizers, markets, finance, extension support, effective national research systems and better rural infrastructure. Almost all these have been addressed in one way or the other by successive Governments in Africa without desired results.

Soil fertility in Africa has been continuously declining due to poor management and yet fertilizers are either too expensive or not available to farmers. Currently, for most African countries, it is more cost effective to import fertilizers than to produce locally, until demand for fertilizer increases to support large-scale production (World Bank, 2006). Thus, more than 90% of fertilizers used in Africa are imported according to World Bank report (2012). Consequently, the rate of fertilizer application in Africa is less than 20% of what obtains in the United States of America or even most Asian countries (Jama et al., 2013). Some African countries have re-introduced fertilizer subsidies but this is not effective in most countries because of corruption, and long bureaucracies in distribution so that the farmers do not get them on time.

Most farmers in Africa still use farmer-saved seeds (seeds from the previous harvest) in spite of the very low yields from such seeds (Mabaya et al., 2013). There are many National and International Research Institutes engaged in development of improved seeds and planting materials in Africa but their capacity is still very limited. Besides, according to Parliamentary Office of Science and Technology (2004), Africa has the world's lowest capacity in personnel involved in agricultural research with only 70 researchers per million inhabitants. Seeds are still relatively expensive for the farmers and most of them still do not know the importance of using improved seeds and the fact that the yields of these seeds decrease with their filial generations. Extension service is none existence in many areas to educate and guide the smallholder farmers to maximize their productivities. There is still a very big controversy in the use of genetically modified (GM) crops. As at 2012, GM crops are grown in 20 developing countries and 8 industrialized countries (Clive, 2012), but only four African countries (Burkina Faso, Egypt, Sudan and South Africa) have started cultivation of GM crops. The total area of GM crops in Africa is 2,801,000 h but South Africa alone has 2,300,000 h of GM crops (82.1%). Most of the farms are rain-fed while most of the farmers lack the essential basic knowhow in agriculture.

Unlike many countries in Asia, Europe and Americas where farmers of some crops are guaranteed prices, farmers in Africa are left at the mercies of the rapid and unpredictable fluctuations in the prices of farm produce. There are both seasonal and annual fluctuations in the prices of produce in some rural areas. Post and on-farm losses and seasonal glut reduce farmers' incentives. In some cases, very high percentages of some crops are not even harvested because of lack of market and storage facilities. According to World Bank report (2010), 11 to 19% of maize is lost in Africa. The percentage losses are even higher for other crops such as cassava, fruits and vegetables. There are only very few or no functional silos and other storage facilities for storage and gradual release of the produce to the market, which would prevent market fluctuations. Furthermore, low cost and subsidized food imports weaken African agricultural markets as many countries subsidize and encourage food production for national security and the surplus are exported to Africa at very low prices, thus unduly completing with domestic production. It is also very important to note that poor distribution network and poor storage facilities are major factors limiting physical food availability in many places in Africa. Thus, while foods are rotting away in some places, the same food items are totally lacking in other places or are too expensive because of the high transportation costs.

Another major problem facing agriculture in Africa is the poor access to credit facilities. Although agriculture represents as much as 40% of gross domestic product (GDP) in some African countries, only 0.25% of bank lending goes to smallholder farmers (AGRA, 2013). Commercial banks are unwilling to give loans to farmers because of the high risks due to uncertainties in weather conditions as well as the non- guaranteed market and prices. There are some Agriculture banks in some countries mandated to give low-interest loans to farmers but these are not enough to meet the huge demand for credit. Besides, these loans are hardly given to the smallholder farmers that make up more than 80% of farmers in Africa because they are not able to meet up with the demands (collateral, among others) while most farmers are not even aware of the loans, and do not know what to do to access the loans.

The complexity of land tenure system in Africa is also a major problem limiting agricultural productivity. Land tenure system varies among African countries and even among the ethnic groups and communities within each country. Both customary (traditional) systems as well as state (statutory) systems operate depending on the place. These systems make it difficult to establish large farms, and in some cases, lands are leased only for short periods of time, thereby making long term investments difficult.

In the face of all these problems, Government expenditure on Agriculture is still very low. The Maputo Declaration by the African heads of state in 2003 to spend at least 10% of their national budgets on Agriculture is not being implemented (Doward and Chirwa, 2009). In 2007, AU/NEPAD survey showed that 50% of African countries spend less than 5% of their national budget on Agriculture. Furthermore, in many African countries, less than 1% of their Agricultural GDP was spent on Agricultural R and D between 2000 and 2008 (Oluoch-Kosura and Sikei, 2013). We tend to believe that we know the problems facing agriculture in Africa, we express our willingness to tackle them yet we are not succeeding. Does this imply that the technologies and knowhow on agricultural production are so complex that Africans cannot learn and adapt? There is definitely a need for radical change in our mind set and approach to boast agricultural productivity in Africa.

HOW TO INCREASE AGRICULTURAL PRODUCTIVITY

Increasing agricultural productivity is important not just for food security but because agricultural sector accounts for a large share of gross domestic product in most African countries, and poverty is concentrated in rural areas where majority are employed in agricultural sector. Furthermore, boasting agricultural productivity is fundamental to development of bio-industries that use agricultural produce as the raw materials. The average agriculture growth rate in Sub-Saharan Africa (excluding South Africa) is estimated to be 4.0% but varies widely among the countries. It is very low in some countries such as Kenya (1.6%) and high in others such as Liberia (9%) and Mozambique (8.7%) (Keita, 2013).

Increasing agricultural productivity in Africa requires a lot in terms of infrastructural development (energy, roads, water and irrigation systems), research and development (development of improved varieties, and efficient agronomic practices) and policy changes aimed at attracting investment in the sector. Farmers must have access to finance, agricultural inputs (fertilizers, good planting materials, and agrochemicals), stable market with minimal transaction costs, and efficient extension service. Most reports on ways of increasing agricultural productivity recommend that Governments must investment on infrastructures (roads, water, power) as well as make favorable policies and interventions such as interest-free or low-interest loans, and subsidies on inputs such as fertilizers and seeds. However, these types of government interventions are very expensive to sustain over a long period of time. Government investment on infrastructure is fundamental to socio-economic development and must be pursued vigorously. However, agricultural subsidies must be seen as a take-off measure to boast agricultural productivity. In most cases, the government interventions are not effective because of poor implementation, corruption, lack of awareness on the part of the intended beneficiaries, and lack of accurate statistics.

The best way to sustain high agricultural productivity is to make farming lucrative even without government interventions. Farming is not a humanitarian venture and must be seen as an integral part of business system. As a business, profit is the most important incentive for investment in agriculture. The efforts of Governments to promote agriculture to achieve national food security must go hand in hand with pure agriculture business by private investors and all the policies and interventions by Governments must not negatively affect private investors in Agriculture. In other words, commercial farmers must be encouraged and protected by government policies. Investment is product demand driven and sustained only by profits. Demand is different from need. The need must be backed with purchasing power. Thus, it can be argued that although most Africans are hungry, there is low demand for food, thereby making foods too cheap to attract investment. In other words, individuals do not have the purchasing power and there is very low level of agro-processing and value addition, resulting in low demand for agriculture produce. The low demand can in turn be blamed for low agricultural productivity. Thus, the smallholder farmers must be encouraged to change from subsistence farming to commercial farming. Because of low profitability in agriculture, many young ones are not interested in farming and even many of those presently engaged in farming are taking it as the last option. The unemployment rate is high, yet most of the unemployed who even have access to land would rather remain idle than farm. Farming must be seen as a lucrative business. To make farming lucrative, the demand must be increased by increasing the purchasing power of individuals, promoting food processing and value addition and establishing ready and stable market for the products which will aid in stabilizing the prices. Primary products are bulky, cheap, perishable and most vulnerable to price fluctuations. Agricultural productivity is highly correlated with proximity to market. Dorosh et al. (2010) reported that total crop production relative to potential production is 45% for areas close to urban cities (markets) but as low as 5% in remote areas in many countries. Foods are produced in rural areas with low demand for the products and the costs of transportation to urban areas coupled with the high transaction costs due to long marketing chains significantly reduce the farmers' profits. Furthermore, reduction of risks and vulnerability is very necessary to increase agricultural productivity. Guaranteed market and prices is needed to absorb surpluses, sustain producer incentives and thus encourage investment. Although putting in place market-supporting institutions and policies can facilitate efficient marketing of products, guaranteed demand is the best option.

HOW TO ACHIEVE FOOD SECURITY

Increasing food production does not mean achieving food security. Based on the definition of food security, a poor person can never be food secured since even if foods are available for sale, he cannot purchase. In other words, hunger (food insecurity at individual level) results from poverty rather than from absolute lack of food. Thus, the problem of poverty must be solved to achieve food security at individual levels. Even at national levels, foods are not available because the countries do not have money to import foods. Agriculture makes up high percentage of most African countries' GDP and yet people are starving and malnourished. Kroma (2013) reported that between 2003 and 2005, agriculture contributed 3.1, 23.1, and 45.8% of GDP for South Africa, Mozambique and Tanzania, respectively. In another report, although share of agriculture in GDP in Sub-Saharan Africa (excluding South Africa) was estimated to be 22.7%, it is very high in some countries such as Sierra Leone (57.6%), and Liberia (53.1%) (Keita, 2013).

Most of the foods are produced in rural areas, yet most of the poor and hungry people are living in rural areas. Agriculture contributes about 53% of total employment in developing countries (Meijerink and Rosa, 2007). In the case of Africa, World Bank report shows that about 80% of rural population in Sub-Saharan African is employed in Agriculture (World Bank, 2012). The figure however varies among the countries. For example, in 2011, agri-culture provided employment for 48.131% of people living in rural areas in Ghana but as high as 84.421% in Uganda (Keita, 2013). Some of them are poor because they produce and cannot sell (there is artificial surplus), or can only sell at very low prices because those who need the food cannot afford to buy at high prices. It can therefore be argued that most of the people living in African rural communities are poor because agriculture is not profitable. Improving the agricultural productivity and profitability is therefore very important as a means of poverty alleviation, increasing their purchasing power and thus their food security levels. Any attempt to increase food production must ensure that the smallholder farmers are protected, and that the measures increase employ-ment opportunities and earnings of the rural communities. Currently, the costs of energy, transport-tation, seeds, fertilizers and other agricultural inputs, and thus the cost of food production are higher in Africa than in other regions of the world. Government subsidies and intervenetions to bring down these costs are expensive, ineffective and non-sustainable. Economy of scale will bring down prices of seeds and fertilizers if their demands increase as a result of increased production. Thus, government can concentrate in provision of energy, construction of roads to reduce transportation costs and provision of other basic infrastructures.

Sustaining high agricultural productivity cannot be achieved if there is no market for the products. The market can only be guaranteed if people have the purchasing power or if there is industrial or export demand for the products. Bioenergy production is one way of creating ready and stable markets for the crops, and creating more jobs for the people which again will increase their purchasing power and thus their food security levels.

BIOENERGY PRODUCTION IN AFRICA

Bioenergy is any form of energy from biomass materials. They include the solid primary energy (fire wood, charcoal and combustible wastes), gasses (biogas and biohydrogen), and liquid fuels (bioethanol and biodiesel). Although fire wood, and charcoal are currently the major source of energy in most African communities (IEA, 2009; Cotula et al., 2008) they are very inefficient and rely on cutting and drying of trees and thus environmentally unfriendly. They are linked to various forms of respiratory problems due to constant inhalation of carbon dioxide, carbon monoxide and other combustion gasses. There are many advantages of developing refined bioenergy industries in Africa. It will help to diversify energy sources and achieve energy security in rural areas. In some remote rural communities, it is cheaper and more feasible to produce bioenergy than to connect to the national power grid. Bio-hydrogen is the cleanest of all the bio-energies since its combustion does not result in any pollution. However, bio-hydrogen production is still very inefficient and expensive and a lot of R and D are still required before commercial bio-hydrogen production (Ogbonna and Tanaka, 2000). Biogas is produced by anaerobic digestion of organic wastes. The technology is very simple and digesters are cheap and easy to maintain. Most of the biogas projects in Africa are designed as waste valorization (conversion of wastes into valuable products) projects aimed at simultaneous treatment of the wastes and production of biogas as well as organic manure. Although there are many small scale biogas production facilities in Africa, most were established as either government or Non-govermental Organisations (NGO) projects rather than as pure commercial ventures. Thus, most of them do not have well-trained personnel to manage them, and are usually abandoned if there is no follow up. Because of the difficulty and costs of collecting wastes from distance places, biogas projects are usually very small and community based. The raw materials are almost free but for the cost of collection and transportation to production plants. They can be house hold, community, animal farm or biomass processing industrial based. Since wastes are the raw material, biogas production does not have any negative effect on food security and therefore highly desirable. Bioethanol and biodiesel have very high potentials in Africa. Bioethanol can be produced from any carbohydrate - containing biomass materials such as sugar crops, starchy materials, and lignocellulosic materials (Ogbonna et al., 2001; Ogbonna, 2004; Ogbonna, 2013). Although most of the current commercial bioethanol industries use food crops such as sugar cane, sugar beet, corn, and cassava, emphasis are shifting to non-food crops and bio-products from crops such as cobs, molasses, bagasse, and fibers. However, the technologies for production of bioethanol from lingo-cellulosic materials are still inefficient and expensive. Currently, South Africa produces 65% of all the bio-ethanol in Africa and this is followed by only 5% produced by Egypt and Nigeria (DFID, 2007). Biodiesels can be produced by esterification of oils of animal, plant or microbial origin. Most of the biodiesels are currently produced from plant oils (jatropha, sunflower, rapeseed, and palm oil) but a lot of projects are on-going for development of commercial processes for biodiesel production by microalgae. Although there are some estimates and reports on some bioenergy production projects in Africa, there are limited reliable data on bio-energy production and utilization in Africa. There are many proposed projects but a lot of them end up at the planning stage or are never completed. Some of such projects were listed by Amigun et al. (2008).

POTENTIALS OF BIOENERGY IN AFRICA

The potential of bioenergy production in Sub-Saharan Africa is very high because almost all the ecological zones can support different types of energy crops. One of the major questions that must be answered why thinking of large scale production of bio-energy is the availability of land. Production of energy crops definitely means competition for land between energy crop and food crop production. Some have argued that large scale production of energy crop will significantly limit the land available for food crop production. On the other hand, there are a lot of reports, indicating that availability of land is not a problem for large scale bioenergy crop production in Africa. Fischer et al. (2002) estimated that there are 807 million of cultivatable lands in Africa and only 197 - 227 million were under cultivation by 1996. It has also been reported that about 70% of cultivatable land in Africa is not cultivated (Alexandratos and Bruinisma, 2012). They estimated that about 183 million hectares of land are under cultivation in Sub-Saharan Africa and about 452 million hectares of suitable land are not being cultivated. Gnansounou et al. (2007) also noted that in some countries in Africa, only 6% of cultivatable land is under cultivation, and UEMO (2008) concluded that availability of land is not a problem in most countries in Africa. According to FAO, area of land under annual or perennial crops increased by more than 50% in many African countries between 1990 and 2011. However, Alexandratos and Bruinisma (2012) predict only an increase of 50 million h in land under cultivation by 2050. To ensure that land availability does not affect food crop production, specified areas of land can be allocated to energy crop production, the exact area depending on the region. For example, ethanol yield from cassava flour is about 0.34 g/g of flour, which is equal to 0.11 g/g-fresh tuber (Ogbonna and Okoli, 2013). Assuming a density of 0.789 g/ml, ethanol yield is then 0.1394 mL/g-tuber. Thus, one ton of cassava will yield 139.4 L of anhydrous ethanol. With an average cassava tuber yield of 12 ton/hectare, one hectare of land will yield 1,672.8 L of anhydrous ethanol. Similarly, with average corn yield of about 1.979 ton/h in Africa, one hectare of land will yield 904.8L of corn ethanol (Ogbonna and Okolo, 2009) but using the world average corn yield of 5.158 ton/h (FAOSTAT, 2013), one hectare of land will yield 2,358.2 L of corn ethanol. Thus, using only ten percentage of uncultivated land in Africa (45.2 million hectares), Africa can produce 1.06×10^{11} L of ethanol per annum, which is higher than the current total fuel ethanol production in the world. In the same way, production of biodiesel using jatropha, for example, is 1,892 L/h (Chisiti, 2007) and 8.55×10^{10} L of biodiesel can be produced from ten percentage of uncultivated land in Africa per year.

It can therefore be argued that with proper planning, significant amount of bioenergy can be produced in Africa without significant effect on land available for food crop production. Furthermore, increasing crop yields will drastically reduce the area of land needed to produce the fixed amount of bio-energies. Average crop yields in Africa are very low because crop production is still characterized by low input/rain-fed crop system. It has been estimated that the yields of cereals in such a system is only about 13.2% of the potential yield in high input/rain-fed systems, and 8.3% of the potential yields in high input irrigated systems (Dorosh et al., 2010). With improved varieties, fertilizer applications and good agronomic practices, we can achieve more than double increase in our crop yields and this has been demonstrated in Millennium villages (Sanchez, 2010), thereby drastically reducing the required area of lands to produce a given volume of bioenergy. Furthermore, labour is generally cheap and available, considering the very high rate of unemployment in Africa.

However, even with availability of land and labour, it is still very important to consider the economic feasibility of large scale production of bio-energy in Africa. Amigun et al. (2008) noted that the economy of bioenergy depends on the cost of raw materials, the biofuel production costs, the cost of corresponding fossil fuel, and the strategic benefit of substituting imported fuel with locally produced biofuels. The cost of raw material has an overwhelming effect on the final cost of production (Ogbonna and Okoli, 2013). There can be more than 50% seasonal variation in the cost of raw materials (crops) used for bioenergy production. The conversion cost remains very low and depends on the technology and scale of production. Because of the problem of equipment maintenance and power supply, process automation should be reduced to minimum in rural communities in Africa. This also has an advantage of providing employment opportunities though the overall efficiency may be lower. The costs of corresponding fossil fuels vary greatly. In some countries such as Nigeria, there is Government subsidy on fossil fuels but in other countries, fossil fuels are very expensive, making bioenergy industries more profitable.

Most bio-energies are insensitive to economies of scale because scale dependent variables such as labour costs represent only very small percentage of the production costs. On the other hand, raw materials which represent more than70% of the final production cost tend to be more expensive as the scale increases because of the increased costs of transporting raw materials from distance farms. Sourcing raw materials from far away farms will increase the cost of transportation, thus, nullifying the advantage of economy of scale. Thus there is often diseconomy of scale in bioenergy production. It is also difficult to find funds for large scale projects because of the huge capital investment costs required. Credit facileties are not easily available, and the interest rates are often too high for farming business. Thus, there is an optimum scale for bio-energy production and the optimum scale depends on the size of the feeding farms and their yields. In most places, small to medium scale bioenergy production facilities may prove more useful, even though the conversion costs may be higher.

Aside from economic viability, energy security issues, environmental and social issues must be considered while making decisions on establishment of bioenergy industries. Many developed countries support bioenergy industries either in form of tax exceptions or subsidies. For example, in France, tax exceptions for biofuels are 0.35 EUR/l for biodiesel and 0.50 EUR/l for bioethanol while subsidy on bio-ethanol is US $0.51/gal in the United States of America (ESMAP, 2005). Unfortunately, some of these government supports are difficult to implement in most African countries because of lack of reliable statistics and implementation capacity/frame work. Nevertheless, supporting such ventures can be an indirect way of genuine support for unemployed youths.

EFFECT OF BIOENERGY PRODUCTION ON FOOD SECURITY

It is very important to understand and appreciate the interrelationship between food security and energy security. Energy security and food security are highly interwoven and inseparable. Energy is needed for production and distribution of food and it is extremely difficult to achieve food security without energy security. As discussed, Africa is energy poor and improving energy production in the continent is fundamental to achieving food security. In Nigeria, for example, any slight increase in the pump prices of fuel has always resulted in sharp increases in the prices of foods and other commodities.

Large scale bio-energy production can have both positive and negative effects on food security. It is feared that if food crops are used for large scale bio-energy production, the increase in demand for the food crops will push the prices up and some school of thought have been insisting that the recent increase in the price of corn in the world market is due to large scale corn ethanol production in the United States of America. However, others have argued that the increase in the grain prices is due to changes in weather conditions rather than bio-energy production. Large scale bio-energy production can also lead to competition for land, labour and other agricultural inputs and may even deprive smallholder farmers their land due to either excessive increase in the prices of lands or government displacing small scale farmers and allocating the land to large scale farmers. These apparent negative effects of large scale bioenergy production on food security cannot be overlooked but can be significantly reduced by proper planning and policies to minimize competition between food and energy production. Land use can be regulated whereby specified area of land is allocated to bioenergy production and the land allocation reviewed from time to time, depending on demands. Small scale farmers should never be deprived of their land but encouraged to engage in a more lucrative farming. They should be encouraged to form cooperative societies for proper coordination and easy access to funds, extension services and various government interventions. Bioenergy companies can organize the smallholder farmers, contract them to produce for them and support them technically and financially.

On the other hand, there are some possible positive effects of bioenergy production on food security. Bioethanol and bio-diesel industries will lead to development of the agricultural sector by creating a stable demand, attracting investment, and thus stimulate R and D that will eventually lead to increases in yields and income for the farmers. Currently, production of food crops fluctuates with weather, especially in most African countries where most farms are rain-fed. Bioenergy production is a very good means of absorbing excess products on good harvest years, thereby stabilizing prices. Thus, it will create stable market and prices for the crops, resulting in higher income for smallholder farmers who are currently the majority in many countries and very poor due to unstable and low prices for their products. Crop production is the major source of household incomes in rural areas. Thus increasing the profitability of farming will drastically reduce poverty which is fundamental to achieving food security. Large scale bioenergy production will also create jobs both in the agricultural sector and the bioenergy production facilities. Madakadze et al. (2013) noted that increasing the level of farm productivity is a prerequisite for economic development. There is a lot of wasted capacity due to high rate of unemployment. Many graduates of Agriculture are without jobs and yet lack of human capital is discussed as one of the major problems facing agriculture in Africa. Large scale bio-energy production will create jobs to absorb all these unemployed graduates. Bioenergy production will lead to total agricultural transformation and mobilize the available knowledge and skills that now lie wasted in many African countries. Bioenergy production can also lead to increase in energy security which in turn will encourage investment

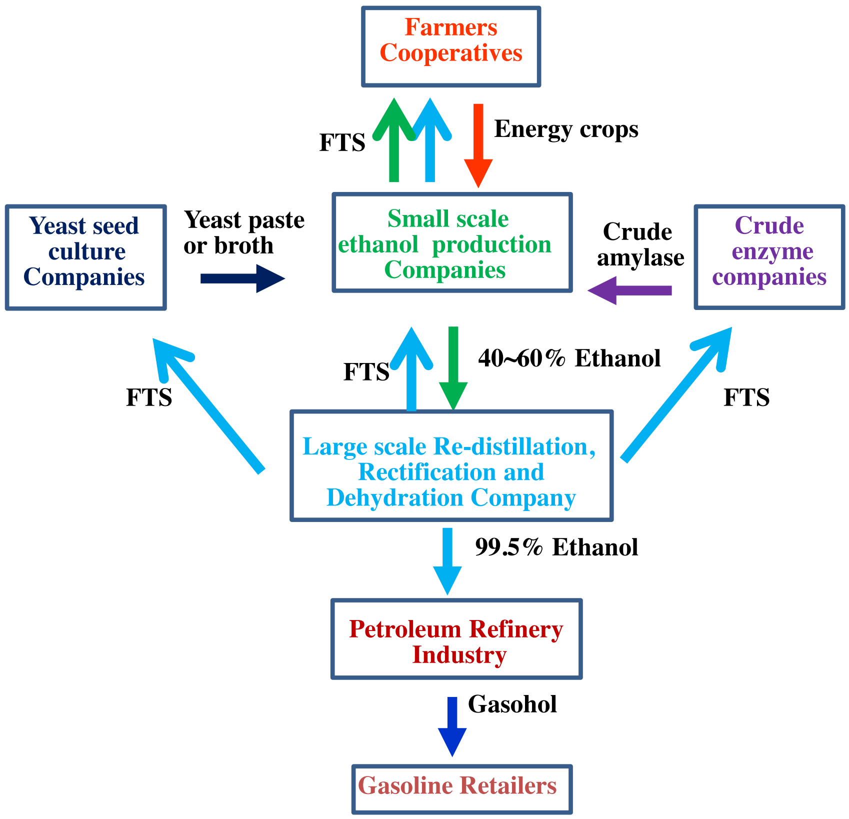

Figure 1. A vertical integrated system for community-based bio-ethanol production. FTS, Financial and technical support.

in other sectors of the economy and thus create more jobs. Bioenergy can stimulate demands for agricultural inputs such as seeds, fertilizers, and other agrochemicals so that suppliers can operate on large scales for reduced unit costs. On the whole, the net effect of bioenergy production on food security would therefore depend on country, locality within the same country and economic groups. However, the above discussions point to the fact that the possible positive effects far outweigh the negative effects.

VERTICAL INTEGRATED SYSTEMS FOR BIOENERGY PRODUCTION

As outlined before, most of the foods consumed in Africa are produced by smallholder farmers. For example, Salami et al. (2010) reported that about 75% of total agricultural output in Kenya, Tanzania, Ethiopia and Uganda are produced by smallholder farmers with average farm size of about 2.5 h. Any program aimed at increasing agricultural production in Africa must therefore be targeted towards protecting and empowering small-holder farmers. Thus, in order to avoid the adverse effects of bio-energy production on food security, and thus realize the various advantages of bio-energy production in Africa, the smallholder farmers must be fully integrated into the bioenergy production, rather than displacing them. Community based bioenergy systems are most appropriate for most rural communities in Africa. Examples of such systems are shown in Figures 1 and 2 for bio-ethanol and bio-diesel, respectively. In the case of bioethanol, large scale Bioethanol Company organizes and provides financial and technical supports to many smallholder farmers, small scale ethanol producers as well as small scale crude enzyme and yeast companies. Small scale ethanol production facilities are established within clusters of smallholder farms to minimize transportation costs for energy crops. The small scale producers buy the energy crops, ferment and distill into about 40~60% ethanol, using simple pot still distillation equipment. These types of pot still can be locally fabricated for reduced costs. These small scale ethanol companies also provide supports to the smallholder farmers. Since pure yeast cells and purified enzymes are often very expensive in most African countries, yeast and crude enzyme production Industries are also established to supply yeast and crude enzymes to the small scale producers. A large re-distillation, rectification and dehydration company buys the ethanol from the small scale producers at fixed prices, re-distill, dehydrate and then sell to petroleum companies for blending.

In the case of bio-diesel production, a big bioenergy

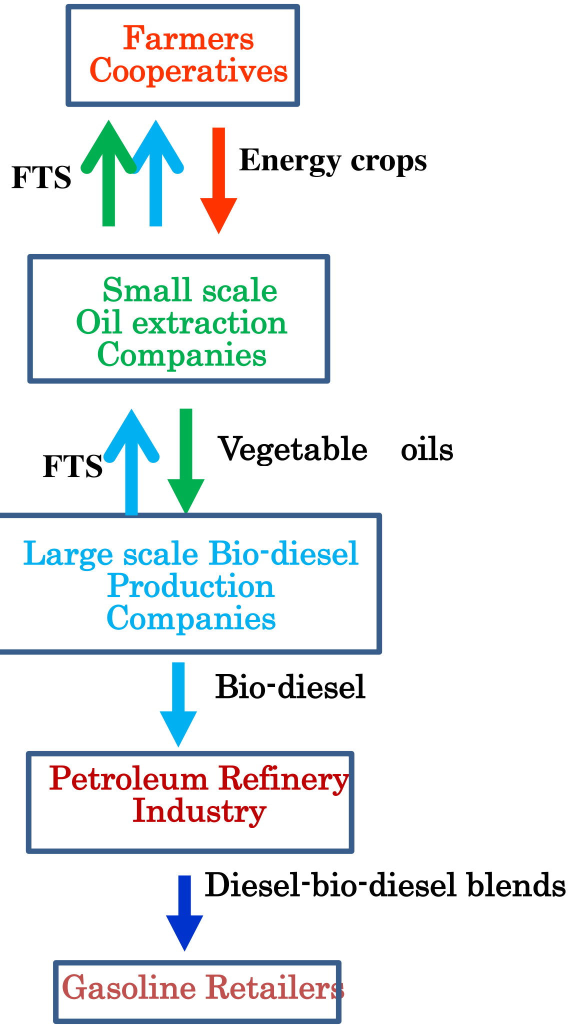

Figure 2. A vertical integrated system for community-based bio-diesel production. FTS, Financial and technical support.

industry also supports the smallholder farmers for increased productivity. Small scale oil extraction companies are established within farm clusters and sell their oil to large scale esterification companies for biodiesel production and distribution. The large scale biodiesel company also provides financial and technical supports to the farmers and small scale oil extractors. The vertical integrated bio-energy production systems have the following advantages:

1) The smallholder farmers are empowered, thus increasing their productivity and earnings.
2) Many jobs are created by the farmers, small scale ethanol producers, oil extractors, and the large bio-energy industries.
3) Transportation costs for the energy crops are significantly reduced.
4 The farmers are protected from fluctuations in prices, and have ready market that guarantees prices for their products.

CONCLUSION

One fundamental problem with policies and strategies for increased agricultural productivity in Africa is lack of reliable statistics on such vital things as the number of farmers, their farm sizes, their location as well as their major crops. Even the total national productions of some staple crops are very rough estimates. Keita (2013) noted that many countries cannot even provide reliable information on land area under cultivation, amounts of important crops produced, yields, amounts consumed, amounts processed, producer prices, and market prices. These types of information are very vital for planning but unfortunately, many countries do not have the capacity to collect and analyze information on farming activities.

Crop yields in Africa is still on average, less than 20% of their potential yields, while less than half of cultivatable lands in Africa are not cultivated. Thus crop production in African can easily be increased far more than their food requirement. With proper planning, large scale bio-energy production can be done without negative effects on food security. This will create jobs, reduce poverty and thus lead to the overall socio-economic development of the continent. However, this requires good policies, initial support and proper implementation.

Aside from bio-energy production from crops, micro-algae biotechnology can also be used for large scale production of bio-diesel without adverse effect on food security. Microalgae have higher photosynthetic efficiencies, thus higher productivities than higher crops, they are very diverse and thus can adapt to many ecological zones, they can be cultivated in non-agri-cultural areas, have high oil contents, and their cultivation can be coupled with waste water treatment, and thermal plants for carbon dioxide reduction. Relatively small area of land is required and Chisti (2007) estimated the productivities of microalgae oils to be 139,900 L/h/year and 58,700 L/h/year for microalgae with oil contents of 70 and 30% in photo bioreactors, while with open ponds, the productivities are 99,400 and 42,600 L/h/year for micro-algae with oil contents of 70 and 30%, respectively. These values are more than one order of magnitude higher than productivities with higher plants. The potentials of algae bio-diesel production have been extensively reviewed (Chisti, 2007; Huntley and Redalje, 2007; Brennan and Owende, 2010), and the climatic conditions in most parts of Africa are favourable for large scale cultivation of microalgae. However, the cost of production of microalgae oil is still very high due to the high costs of constructing and operating closed photo-bioreactors with good light supply on the one hand, and the problems of contamination, low cell growth rates and low biomass concentrations in open air photo bioreactors on the other hand (Ogbonna, 2003). Furthermore, the cost of harvesting from low standing biomass concentrations is still very high and thus requires process improvement. There is also a need for genetic improvement of microalgae strains for increased growth rate, increased oil contents, and improved quality of the oils.

It is also important to note that the proposed vertical integrated system can be made more sustainable and profitable by integrating co-production of high value compounds such as potable alcohols, vitamins, organic acids, amino acids and various pharmaceuticals from the energy crops. Furthermore, efficient utilization and bio-conversion of wastes will definitely increase the profitability of the system. This includes conversion of the tuber peels and lignocellulosic wastes to organic manure, production of animal feeds from other solid wastes such as distillery wastes and solid wastes after oil extraction, recovery of glycerol during biodiesel production as well as recovery and purification of carbon dioxide for beverage industries.

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