



Energy Resource from Agriculture: Prospects and Problems

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ABSTRACT

This paper examines the links between agriculture and energy. It highlights the role of agriculture as an energy, food and industrial raw materials producer. This function implies greater agricultural productivity and higher levels of energy sustainability through the production of CO₂-neutral bioenergy. Biomass was the main source of energy until the early 20th century. However, biomass energy was relegated and ignored by policy makers and energy planners alike during the past few decades. Biomass is defined as all organic matter except fossil fuels. Biomass comes in many forms: wood, annual crops, crop residues, animal manure, marine plants, algae, and others. Biomass may be burned directly to produce heat or converted to more useful solid, liquid or gaseous forms. Then it can be stored and subsequently used for fuel. Before energy can be used for end-use activities, it often has to be converted from its primary (raw) form into a form that is more convenient for transport and use. The processes of conversion of biomass to fuel are: 1. Production of Fuelwood still remain drying and resizing by cutting and splitting into sizes that are easy to transport. Fuelwood includes "wood in the rough" in small pieces, chips, pellets and/or powder (sawdust) derived from forests and isolated trees, as well as wood by-products from the wood industry and from wasted wood products. 2. Charcoal is produced in kilns by a process called pyrolysis, i.e. breaking down the chemical structure of wood under high temperature in the absence of air. 3. Briquetting or densification is process of compacting biomass material, and depending on the nature of the material, the applied pressure, and the speed of densification, additional binders may be needed to bind the material. 4. Gasification is the process in which solid biomass fuels (e.g. wood, charcoal) are broken down by the use of heat to produce a combustible gas, known as producer gas. 5. Ethanol can be produced by the fermentation of glucose derived from sugar-bearing plants (like sugar-cane) or starchy materials (like cassava) after hydrolysis. 6. Biodiesel is produced through transesterification process. This involves vegetable or animal fats and oils being reacted with short-chain alcohols (typically methanol or ethanol) in the presence of catalyst, producing biodiesel and glycerol. A transition to more sustainable rural energy systems is urgent, and agriculture could make an important contribution in this respect. A more extensive use of bioenergy will lead to considerable benefits to the global environment and to the development of local infrastructure, but the potential conflicts with food production and impacts of land use change must be followed closely. FAO is currently strengthening its bioenergy programme with the aim of contributing to a partial substitution of fossil fuels with biofuels.

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INTRODUCTION

Agriculture is the practice of cultivating the soil and raising livestock to produce plant and animals useful to humans and in some instances to the animals (Asoegwu and Asoegwu, 2007). Also, according to WMO (1972) Agriculture is the art of converting the energy of solar radiation into fuel for consumption by the human machine. Hence, agriculture could also be seen as a way of life, occupation or business to produce food, feed, fiber, fur and fuel.

The primary role of agriculture is to produce food and other primary goods and thereby contributing to food security. The concept of Sustainable Agriculture and Rural Development (SARD) is to foster sustainable development in the agriculture, fisheries and forestry sectors, in order to conserve land, water, plant and animal genetic resources. Attaining food security requires policies that can ensure social, cultural, political, and economic stability. Combining the economic, social and environmental functions of agriculture can help to achieve these goals (FAO, 1999a).

Energy is a vital input for both rural economy and the modern industrial economy. It is essential for almost all human activities: it provides services for cooking and space/water heating, lighting, health, food production and storage, education, mineral extraction, industrial production and transportation (Stout, 1990). Modern energy services are a powerful engine of economic and social development, and no country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population. Throughout the world, the energy resources available to people and their ability to pay, largely determine the way in which people live their lives. Nevertheless, it is critical to recognize that what people want are the services that energy provides, not fuel or electricity.

The role of agriculture as a major energy supply sector is rarely recognized or put into practice. Awareness of the potential for bioenergy as an economic driver for rural development, together with growing attention to global climate change have highlighted this new approach to the energy function of agriculture (FAO, 2000a). Agriculture has delivered a wide range of non-food goods and services. This includes its use as a viable, sustainable source of energy. It can give social, environmental and economic benefits, and can also provide a legitimate energy supply function. Biofuels can, therefore, make a significant contribution to climate change mitigation through CO₂ substitution. The world-wide potential for energy supply from energy crops is very large and biomass could, in theory, substitute for as much as 25% of the world's use of fossil fuels. Bacteria convert about 90% of the feedstock energy content into biogas (containing about 55% methane), which is a readily useable energy source for cooking and lighting (FAO, 2000a). The sludge produced after the manure has passed through the digester is non-toxic and odourless. Also, it has lost relatively little of its nitrogen or other nutrients during the digestion process thus, making a good fertilizer (FAO, 2000a).

In the early 1900's, energy sources around the world were mostly agriculturally derived and industrial products were primarily made from plant matter. Early motor fuels also came from agriculture- the original engine of Henry Ford used ethanol while the Rudolf Diesel's engine used peanut oil (Duffield, 2006). This paper reviews the role that agriculture could play as an energy provider, identifies the sources of agriculturally derived energy, and highlights the

techniques of biofuels production and the prospects of bioenergy and also identifies problems of bioenergy

ENERGY SOURCES FROM AGRICULTURE

Biomass

Biomass was the main source of energy until the early 20th century. It was only during the past few decades, when biomass energy was relegated and ignored by policy makers and energy planners alike. Current trends indicate that the amount of bioenergy used remains stable (or even growing) with an increased use in industrial countries such as EU members and USA, mainly for environmental rather than purely energy reasons (Stout, 1990). Biomass is defined as all organic matter except fossil fuels. Biomass comes in many forms: wood, annual crops, crop residues, animal manure, marine plants, algae, and others (Stout, 1990). Biomass may be burned directly to produce heat or converted to more useful solid, liquid or gaseous forms. Then it can be stored and subsequently used for fuel.

Biofuels

Biofuels are organic primary and/or secondary fuels derived from biomass which can be used for the generation of thermal energy by combustion or by using other technology. They comprise purpose-grown energy crops, as well as multipurpose plantations and by-products (residues and wastes). There are three main biofuel categories: Woodfuels, Agrofuels and Municipal wastes (FAO, 2000b).

Wood fuels

These are wood in form of fuel-wood, sawdust and charcoal, they are the major source of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption (Akinbami, 2001). Adegbulugbe (1994) reported that the demand for fuelwood is expected to have risen to about 213.4 x 10³ metric tons, while the supply would have decreased to about 28.4 x 10³ metric tons by the year 2030. The most commonly used types of wood-fuels are fuel-wood and charcoal, which can be burned in both traditional and modern energy systems for cooking and heating. Other fuels, such as chips, wood powder (sawdust), pellets, briquettes, methanol, ethanol, pyrolysis gases, producer gas, etc., can also be derived from wood-fuel.

Agro-fuels

Fuel obtained as a product of agricultural biomass and by-products. It covers mainly biomass materials derived directly from fuel crops and

agricultural, agro-industrial and animal by-products (Best, 1997).

Municipal Wastes

These refer to biomass wastes produced by the urban population and consist of two types of products: solid municipal by-products and gas/liquid municipal by-products produced in cities and villages.

PRODUCTION OF BIOFUEL

Before energy can be used for end-use activities, it often has to be converted from its primary (raw) form into a form that is more convenient for transport and use. The processes of conversion of biomass to fuel are described as follows:

Wood-fuels

Wood is converted into other forms for energy purposes, such as fuel-wood, charcoal, briquettes, gas and ethanol. Wood energy conversion technologies range from simple, traditional processes such as charcoal production in earth mounds to modern, highly efficient processes, such as dendro power and co-generation.

Fuel wood

The production process of fuelwood still remain drying and resizing by cutting and splitting into sizes that are easy to transport. Fuelwood includes "wood in the rough" in small pieces, chips, pellets and/or powder (sawdust) derived from forests and isolated trees, as well as wood by-products from the wood industry and from wasted wood products (Bugaje 2008). Figure 1 shows fuel-wood gathered from pruned trees around the Faculty of Engineering, University of Maiduguri.

Charcoal

Mostly, charcoal is produced from wood, but other sources may be coconut shells and crop residues in kilns by a process called pyrolysis, i.e. breaking down the chemical structure of wood under high temperature in the absence of air (FAO, 1997). During the process, first water is driven out from the wood (drying), and then the pyrolysis starts when the temperature in the kiln is high enough (500 - 800 °C). When the pyrolysis is complete, the kiln gradually cools down, after which the charcoal can be removed from the kiln. Because some of the wood is burned to drive off the water, dry wood produces better charcoal at a higher efficiency. Typically, around two-thirds of the energy is lost in the process, but charcoal has

advantages of having higher efficiency, higher convenience and easier distribution over fuel wood.

The oldest and probably still the most widely used method for charcoal production is the earth kiln. Two varieties exist, the earth pit kiln and the earth mound kiln. An earth pit kiln is constructed by first digging a small pit in the ground. Then the wood is placed in the pit and lit from the bottom, after which the pit is first covered with green leaves or metal sheets and then with earth to prevent complete burning of the wood. The earth mound kiln is built by covering a mound or pile of wood on the ground with earth. The mound is preferred over the pit where the soil is rocky, hard or shallow, or the water table is high. Mounds can also be built over a long period, by stacking gathered wood in position and allowing it to dry before covering and burning.

Portable steel kilns can be made from oil drums, and can be used both in horizontal and vertical position. They generally have a short lifetime. When used in the horizontal position, an opening is made in the side, through which the wood is loaded. For the vertical kiln the top is cut out and used as a lid (Maxwel, 2009). Figure 2 shows a locally produced portable kiln for charcoal production.

Briquetting

Briquetting or densification is used to improve characteristics of biomass to overcome the bulky nature, low thermal efficiency smoke emission, easy transportation and use as energy source. Raw materials include sawdust, loose crop residues, and charcoal fines. Bugaje (2008) reported that several machines have been developed in Nigeria for briquettes production, including a single cylinder extrusion machine that transforms rice, millet and sawdust husk to briquettes that produce 13 kg of briquettes per hour. In briquetting, the biomass material is compacted, and depending on the nature of the material, the applied pressure, and the speed of densification, additional binders may be needed to bind the material (Oladapo, 2008; Oumarou and Oluwole, 2010). Figure 3 shows locally produced briquettes made from sawdust. The two main briquetting technologies are the piston press and the screw press. In the piston press the material is punched into a die by a ram with a high pressure (Olorunnisola, 2007). In the screw press, the material is compacted continuously by a screw. With the screw press, generally briquettes of higher quality can be produced. Bugaje and

Mohammed (2007) reported that the locally produced briquette has 6 to 7 times more energy content per unit volume than unbriquetted

biomass and in addition, the heating flame and temperature obtained in the cooking process are better.



Figure 1. Fuelwood gathered from pruned trees around the Faculty of Engineering University of Maiduguri



Figure 2. Portable steel kilns for charcoal production. Source (Maxwel, 2009)



Figure 3 Locally produced briquettes from sawdust

Gasification

This is the process in which solid biomass fuels (e.g. wood, charcoal) are broken down by the use of heat to produce a combustible gas, known as producer gas. High temperatures and a controlled environment lead to virtually all the raw material being converted to gas. This takes place in two stages. In the first stage, the biomass is partially combusted to form producer gas and charcoal. In the second stage, the CO_2 and H_2O produced in the first stage are chemically reduced by the charcoal, forming CO and H_2 . The composition of the gas is 18 to 20% H_2 , an equal portion of CO , 2 to 3% CH_4 , 8 to 10% CO_2 , and the rest nitrogen. These stages are spatially separated in the gasifier, with gasifier design very much dependant on the feedstock characteristics (Stanhill, 1984).

Gasification requires temperatures of about 800°C and is carried out in closed top or open top gasifiers. These gasifiers can be operated at atmospheric pressure or higher. The energy density of the gas is generally less than 5.6 MJ/m^3 , which is low in comparison to natural gas at 38 MJ/m^3 , providing only 60% the power rating of diesel when used in a modified diesel engine (Stanhill, 1984).

Pyrolysis

In pyrolysis, the biomass feedstock is subjected to high temperatures at low oxygen levels, thus inhibiting complete combustion, and may be carried out under pressure. Biomass is degraded to single carbon molecules (CH_4 and CO) and H_2 producing a gaseous mixture called "producer gas." Carbon dioxide may be produced as well, but under the pyrolytic conditions of the reactor it is reduced back to CO and H_2O ; this

water further aids the reaction. Liquid phase products result from temperatures which are too low to crack all the long chain carbon molecules so resulting in the production of tars, oils, methanol, acetone, etc. Once all the volatiles have been driven off, the residual biomass is in the form of char which is virtually pure carbon (Stanhill, 1984).

Pyrolysis has received attention recently for the production of liquid fuels from cellulosic feedstock by "fast" and "flash" pyrolysis in which the biomass has a short residence time in the reactor. A more detailed understanding of the physical and chemical properties governing the pyrolytic reactions has allowed the optimisation of reactor conditions necessary for these types of pyrolysis. Further work is now concentrating on the use of high pressure reactor conditions to produce hydrogen and on low pressure catalytic techniques (requiring zeolites) for alcohol production from the pyrolytic oil (FAO, 1997).

AGROFUELS

Fuel crops

This is employed to describe species of plants cultivated on plantations or farms to produce raw material for the production of biofuel. The fuel crops can be produced on land farms (manioc, sugar cane, euphorbia, etc.), on marine farms (algae) or in fresh water farms (water hyacinths). The land-produced fuel crops can also be classified under: sugar/starch crops, oil crops and other energy crops.

Sugar/starch crops

These are crops planted basically for the production of ethanol (ethyl alcohol) mainly as a fuel used in transport (on its own or blended with gasoline).

Ethanol Production

Ethanol can be produced by the fermentation of glucose derived from sugar-bearing plants (like sugar-cane) or starchy materials (like cassava) after hydrolysis.

Most ethanol is produced using a four-step process:

1. The ethanol feedstock (crops or plants) are ground up for easier processing;
2. Sugar is dissolved from the ground material, or the starch or cellulose is converted into sugar. This is done through a cooking process.
3. Microbes such as yeast or bacteria feed on the sugar, producing ethanol in a process called fermentation; essentially the same way beer and wine are made. Carbon dioxide is a byproduct of this fermentation;
4. The ethanol is distilled to achieve a high concentration. Gasoline or another additive is added so it cannot be consumed by humans - a process called denaturation.

(<https://www.thoughtco.com/how-ethanol-is-made>, 2019)

Ethanol is mainly used as a substitute for Premium Motor Spirit (PMS) in spark ignition (S.I) engines. The substantial gains made in fermentation technologies now make the production of ethanol for use as a petroleum substitute and fuel enhancer, both economically competitive (given certain assumptions) and environmentally beneficial. Research work is currently going on to improve the traditional ethanol production in Nigeria (Ngala *et al*, 2006, Abdulrahim *et al*, 2007, Maina *et al.*, 2017). The most commonly used feedstock are sugar-bearing plants and starchy materials.

Oil crops

These cover oleaginous plants (like sunflower, rape, castor seed, Jatropha, etc.) planted for direct energy use of vegetable oil extracted, or as raw material for further

conversion into a diesel substitute, using transesterification processes (Stanhill, 1984).

Biodiesel Production

Biodiesel is produced through transesterification process. This involves vegetable or animal fats and oils being reacted with short-chain alcohols (typically methanol or ethanol) in the presence of catalyst, producing biodiesel and glycerol. The alcohols used should be of low molecular weight, ethanol being one of the most used for its low cost. However, greater conversions into biodiesel can be reached using methanol. The catalyst could either be acids or bases the most common means of production is base-catalyzed transesterification. This path has lower reaction times and catalyst cost than those posed by acid catalysis. However, alkaline catalysis has the disadvantage of its high sensitivity to both water and free fatty acids present in the oils (Oluwole *et al.*, 2017).

The use of vegetable oils for combustion in diesel engines has occurred for over 100 years. In fact, Rudolf Diesel tested his first prototype on vegetable oils, which can be used, "raw", in an emergency. The raw oil can be obtained from a variety of annual and perennial plant species. Perennials include coconut, oil palms, physica nut and Chinese tallow tree. Annuals include sunflower, groundnut, soybean, castor seed, melon seed, sesame seed, Jatropha and rapeseed. Many of these plants can produce high yields of oil, with positive energy and carbon balances. In Nigeria, vegetable oils from groundnut, sunflower, melon seed, sesame seed, etc offer the advantage that they could be extracted and purified traditionally. Some researchers have been working on how to improve the traditional methods of vegetable oil extraction, example are groundnut oil (Uziak and Loukanov, 2007, Oluwole *et al* 2016), sunflower oil (Bamgboye and Adejumo, 2007), edible oils (Bera *et al* 2006), sesame seed (Akinoso *et al* 2006), beniseed oil (Olayanju *et al* 2006). Figure 4 shows oil extractors.

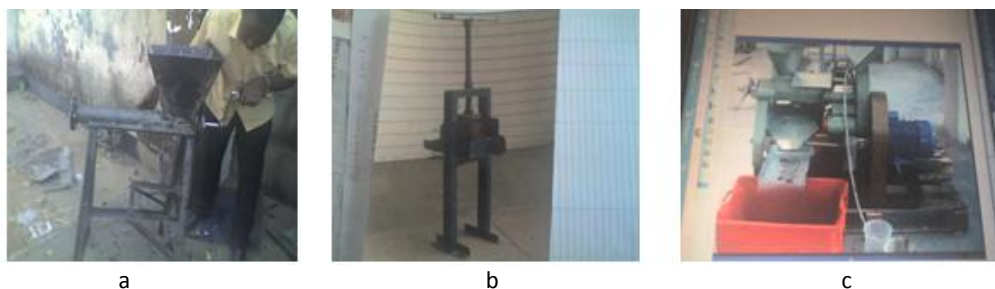


Figure 4. a- Neem seed oil extractor (Umar, 2009); b- Groundnut oil extractor (Oluwole *et al*, 2016)
c- Continuous oil expeller

MUNICIPAL BY-PRODUCTS

Anaerobic fermentation

Anaerobic reactors are generally used for the production of methane rich biogas from manure (human and animal) (Oumarou, 1995), grass species (Mahnert *et al*, 2005) and crop residues (Plochl and Heiermann, 2006). They utilise mixed methanogenic bacterial cultures which are characterized by defined optimal temperature ranges for growth. These mixed cultures allow digesters to be operated over a wide temperature range i.e. above 0°C up to 60°C.

When functioning well, the bacteria convert about 90% of the feedstock energy content into biogas (containing about 55% methane), which is a readily useable energy source for cooking and lighting. The sludge produced after the manure has passed through the digester is non-toxic and odourless. Also, it has lost relatively little of its nitrogen or other nutrients during the digestion process thus, making a good fertiliser. In fact, compared to cattle manure left to dry in the field the digester sludge has higher nitrogen content; many of the nitrogen compounds in fresh manure become volatilised whilst drying in the sun. On the other hand, in the digested sludge little of the nitrogen is volatilised, and some of the nitrogen is converted into urea. Urea is more readily accessible by plants than many of the nitrogen compounds found in dung, and thus the fertiliser value of the sludge is actually higher than that of fresh dung. (FAO, 1995)

Anaerobic digesters of various types were widely distributed throughout India, Thailand, Indonesia and China, only a handful of biogas digesters presently exist in Nigeria (Bugaje, 2008). So far, less than 20 pilot projects on biogas have

been established across the country, including a UNDP pilot project in Kano State (ECN, 2005). Health benefits primarily arise from the cleaner combustion products of biogas as opposed to other biomass or fossil fuels which may be used in the domestic environment. India and China have an estimated 5 to 6 million units in use (FAO, 1994).

Methane Production in Landfills

Anaerobic digestion in landfills is brought about by the microbial decomposition of the organic matter in refuse. The levels of organic matter produced per capita vary considerably from developed to developing countries e.g., the percentage of Municipal Solid Waste (MSW) which is putrescible in Sierra Leone is about 90%, compared to about 60% for US MSW. The reduced levels of putrescible in US, MSW are as a result of the increased proportions of plastics, metals and glass, mostly from packaging. Landfill-generated gas is on average half methane and half carbon dioxide with an energy content of 18 to 19 MJ/m³. Its production does not occur under pressure, and thus recovery processes must be active (FAO, 1994).

Agricultural Residues

They are mainly vegetal materials and by-products derived from production, harvesting, and transportation and processing in farming areas (FAO, 2000a). It includes, among others, maize cobs and stalks, wheat stalks and husks, groundnut husks, cotton stalks, mustard stalks, etc. Figure 5 shows some Agricultural waste in University of Maiduguri.



Figure 5. Agricultural wastes at the back of Faculty of Engineering University of Maiduguri

Table 1 presents some examples of dedicated energy crops, the conversion technologies being developed for their

exploitation and the energy and food products that can be produced from them.

Table 1: Examples of dedicated energy crops

Feedstock	Conversion technology	Products
Sugar cane	Gasification/existing boiler	Electricity/Sugar
Switchgrass, wood residues	Gasification/co-firing	Electricity
Sorghum, switchgrass, silver maple, cottonwood	Pyrolysis/combustion turbine	Electricity/Charcoal
Willow	Co-firing/combustion	Electricity
Alfalfa	Co-firing./gasification combined cycle	Electricity/Animal feed
Pine	Gasification combined cycle Co-generation/alcohol production	Electricity/ Ethanol
Elephant grass, sugarcane, eucalyptus	Combustion/fermentation	Electricity/ Ethanol

Source: (Overend, 1999)

BENEFITS OF BIOFUEL

Climate Change Mitigation

The exploitation and commercialization of biomass through modern technologies offer significant cost-effective opportunities for meeting emission reduction targets while providing additional economic and social benefits. Bioenergy provides a sustainable use of accumulated carbon and acts as a substitute for the use of fossil fuels (IEA, 1998).

All forms of biomass utilization can be considered part of a closed carbon cycle. Biomass utilization through the substitution of fossil fuels will reduce CO₂ emissions, and a combination of biomass with carbon sink options can provide a viable route to climate change mitigation (FAO, 1999).

Job Creation

Bioenergy can contribute to sustainable development in developing countries, provided that a number of key issues related to the practical exploitation of this resource are carefully considered. Biomass sources are more spatially dispersed than fossil fuels, and modern biomass technologies have the potential for generating employment and assisting economic growth in rural areas. Current bioenergy sources are mainly forest and agriculture residues, but in the future dedicated energy plantations could provide additional sources, opening up new opportunities for agriculture and forestry in the energy market. Bioenergy systems are important employment and income generators.

Social and Environmental Benefits

The production and use of Bioenergy has important impacts on the local environment, human health and quality of life. The present patterns of biomass use prevailing in many households in Nigeria are the cause of human drudgery in the process of collection of wood, and

of a large incidence of lung illnesses due to the smoke, especially in children and women. Therefore the "upgrading" of the forms of production and use of these resources needs urgent attention. Fuel saving stoves, biogas digesters and other decentralized systems offer excellent opportunities in this respect.

The sustainable production of biomass fuels and the use of present agricultural and forestry derived residues can play an important role in reducing the need for Green House Gases (GHG) and acid rain emitting fossil fuels. Sustainably grown biomass fuels are CO₂-neutral and low in sulphur and the recycling of the ashes arising from combustion reduces the need for fertilisers. Wider revegetation programmes aimed at reabsorbing atmospheric CO₂ may result in large quantities of low cost biomass being available which should be used as a supplement/substitute for fossil fuels or to produce long lived products.

Similarly, interms of erosion control, biofuels offer some benefits. Bioenergy programmes, when coupled with agro-forestry and integrated farming, have the potential to improve food production by making both energy crops and income available. Increasing agricultural production of biomass can be achieved by substituting for other agricultural crops that are in surplus, intermixing energy crops with food or forage crops in an agro-forestry approach, and incorporating into land conservation systems such as windbreaks and shelter-belts. There is also potential to increase the use of crop residues provided this is consistent with the levels of organic matter and control of erosion.

Reforestation

The establishment of biomass plantation for energy production in parallel with the prospects of increased food production would be of benefit for large areas of deforested and

degraded land. This estimate ranges up to over 300 Mha available for reforestation and agro-forestry (FAO, 1999a). Other studies of the potential cropland resources in developing countries have indicated that these countries will be using only 40% of their potential cropland in 2025 (FAO, 1996). The balance between higher yields in good lands and the benefits of bringing back into production degraded lands is an important issue.

Rural Development

If bioenergy becomes a major source of energy, it could have a profound influence in many rural areas; it could speed up socio-economic development as large number of farmers could increase food production and their own energy in a sustainable manner. This could be done through efficient use of residues and combine agriculture-energy crop systems (FAO/Netherlands, 1999b). This would improve the life of the people leaving in the rural areas.

Reduction of Product Waste

In Nigeria, large quantities of agricultural and forestry residues produced annually are vastly under-utilized. The common practice is to burn these residues or leave them to decompose (Olorunnisola 1998, Jekayinfa and Omisakin 1995). However, previous studies have shown that these residues could be processed into upgraded solid fuel products such as briquettes. A number of such locally available materials briquetted for fuel energy production include sawdust, cowpea chaffs, corncobs, and water hyacinth (Faborode 1988, Adekoya 1989, Ajayi and Lawal 1995, Olorunnisola 1998, 1999). However, in many of the foregoing studies, the briquettes were produced with the aid of binders such as cassava starch and palm oil sludge which tends to produce smoky briquettes. Briquetting of biomass residues for fuel is an important option for substitution of wood and loose biomass residue fuels, under certain conditions. However, the option should be carefully evaluated and any implementation should be based on a thorough understanding of the requirements and constraints.

PROBLEMS OF BIOFUEL

Conflict between Food and Energy Crops

The production of energy crops may however affect food crops production if the energy crops are more profitable than the food crops. With many people in developing countries still undernourished, it is a justified concern that there should be sufficient land for food production and that food should be the priority. However, food

production is a complex socio-economic, political and cultural issue that goes beyond the earth's carrying capacity to grow food crops.

Land Availability

Land availability is often seen as a constraint to the production of energy crops, because most of the arable lands are used for the production of food crops. However, in rural communities in developing countries, both food and energy crops can be integrated into complementary land use systems. However, at the larger scale, land use conflicts may occur where dedicated energy plantations are required to supply a central energy conversion facility.

Technology Development

Whilst certain bioenergy technologies are commercially available or near-market, some of the new conversion technologies are still to be satisfactorily demonstrated, and further research and development work will be needed to exploit fully the potential of modern bioenergy for rural energy services.

Planning and Participation

Sustainable bioenergy production requires detailed local-level planning and the participation of local people, together with a realistic assessment of the biomass resource. Investors and biomass plant operators need to be sure that there is an external market for the power produced and that this market is not artificially constrained against rural energy generating capacity.

Bioenergy requires clearly established legislation and property rights. Since the "product", energy, is related to different markets and thus different marketing routes, it is very probable that its commercialization from the field to the final user crosses different paths than that of conventional agricultural or forestry produce. Therefore, a broader and longer term perspective needs to be applied when considering biomass for energy. Poverty in rural areas requires urgent actions, and the role of bioenergy in this respect needs to be "unleashed". Countries have their own institutional and policy structures and this need to be assessed in the light of bioenergy opportunities. Rural development banks, extension services, local organizations, the private sector and NGOs need to be made aware of bioenergy opportunities. Training of their personnel and designing new loan and small grant schemes need to be put in place. Monopolistic barriers limiting the possibility of decentralized power generation or the distribution of liquid fuels must be cancelled. Finally, it must be

stressed that institutional cooperation on bioenergy is essential, since many technical, social, legal and economic fields need to converge on common goals.

CONCLUSION

In conclusion, the paper has reviewed the role played by agriculture as an energy provider; sources of agriculturally derived energy have been identified such as wood-fuels, agro-fuels, agro-industrial by-product etc. Techniques of biofuels production were highlighted and prospects/problems of bio-fuel production were identified.

RECOMMENDATIONS

At the end of this work, the following recommendations were made:

1. The energy function of agriculture needs to be brought to the level of national policy in Nigeria.
2. Actions such as bioenergy policy support, institutional strengthening, capacity building, research and development activities and technology development work are very important.
3. Rural energy projects should be sustainable, by tackling and overcoming social, cultural, institutional, legal and financial barriers.
4. The potential of biofuel and renewable energy in general should be recognize to assist both in the provision of energy services in the rural areas of developing countries and in the transition process to a more sustainable energy supply.
5. The prospect of private sector finance for sustainable biofuel projects that have the potential for delivering the energy function of agriculture should be included in the policy formulation.
6. For the energy function of agriculture to play its full role, incentives will be necessary to put bio-fuel on more equal terms with conventional fuels, and major Research and Development, technology development and policy gaps need to be addressed.

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