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Assessment of Feedstock Options for Biofuels Production in Ghana

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ABSTRACT

In the wake of climate change and increasing fossil fuel prices, biofuels are becoming attractive to agricultural dependent economies in sub-Saharan Africa and other regions of the world. This study evaluates the energy production potential of biomass resources grown on the available arable agricultural land under two principal scenarios: using 2.5% and 5% of the available arable land for energy crop expansion. Using conservative biofuel yields from crops in the sub-region, a 2.5% of uncultivated arable land dedicated to four traditional crops grown in Ghana namely maize, cassava, sweet sorghum and oil palm could potentially replace 9.3% and 7.2% of transportation fuels by 2020 and 2030 respectively. Using 5% of the uncultivated arable land to cultivate the above four crops and jatropha could potentially produce biofuel to replace 17.3% of transport fuels by 2020 and 13.3% by 2030. In order to enrol such a scheme, government is encouraged to put in place appropriate structures to ensure that, the industry meet international sustainability standards.

Keywords: Biofuels; Feedstock; Ghana

1. Introduction

As energy demand grows, self-sufficiency in energy requirement has become critical to the socio-economic development of most developing countries. The growth in energy demand due to rapid industrialization and socio-economic growth require huge investments to meet them. For decades now, fossil oil has contributed immensely to meeting these demands. However, increasing concerns about emissions from fossil fuels and the impending peak oil theory [1-4] have stimulated interest for alternative energy sources. An alternative fuel must be technically feasible, economically competitive, environmentally acceptable, and readily available [5]. Biofuel produced from energy crops and other resources has been touted as one of the viable sources of energy for the foreseeable future in dealing with these worldwide socioeconomic and environmental concerns [6,7]. Global production of biofuel has been growing rapidly in recent years, rising from about 18 billion litres in 2000 to 105 billion litres in 2010 [8]. Despite this exponential increase, biofuel still represents a very small share of global energy consumption. Biofuels provided 2.7% of all global fuel for road transportation in 2010—an increase from 2% in 2009. As usual, supply is dominated by bioethanol, which accounted for approximately 82% of total biofuel production in 2010. Ethanol's contribution is largely responsible for the increase in biofuel production. Together, Brazil and the US contributed about 90% of global ethanol production with the European Union contributing about 53% of all biodiesel in 2010. Global demand for biofuel is projected to increase to about 183.8 billion litres by 2015 with ethanol expected to contribute about 80% of the total [9]. Already, several countries have adopted policies to promote liquid biofuel development led by the US, the EU, Brazil, Canada, Australia and Japan [10]. A growing number of developing countries, including a few African countries have also started to introduce similar policies. Notable countries in Africa with biofuel strategies in place are South Africa, Mozambique, Ethiopia, Senegal and Mali.

In Ghana, a draft bioenergy policy of 2010 [11] aims to substitute national petroleum fuels consumption with 10% biofuel by 2020 and 20% by 2030. The policy intends to make use of the country's vast biomass potential and resources in modern applications for the production of transport fuels and electricity. Biomass already dominates the energy consumption pattern in Ghana, accounting for over 63% of total energy consumed [12] but used principally in traditional cookstoves as firewood and charcoal. Liquid biofuel use is not commercialised in the country but there are plans to begin commercial production as soon as the infrastructure is in place. Plans for biodiesel production are at a more advanced stage as opposed to those for ethanol production. The draft bioenergy policy is open to the commercial scale production of biofuel feedstocks to sustain supply but is not targeting any specific energy crop(s) to meet the demand targets. In the past, jatropha was thought to be the best feedstock due to previous impression that it was drought resistant. But current research has shown that jatropha may not be the wonder crop that it was thought to be [13].

With conflicting reports on the prospects or potential of jatropha and recent revelations that it performs poorly in marginal lands [13], there is the need to perform an analysis of possible biofuel feedstock choices in order to recommend the best choices to investors and policy makers. The aim of this study was to perform an analysis of the technical potential of first-generation biofuels from energy crops in Ghana. The study aims to contribute knowledge to the call from Ghana's Energy Commission for research support to select the best biofuel feedstock options for the country. Knowledge about the technical potentials would enable a good estimation of land occupancy to attain biofuel targets proposed by the Energy Commission. This paper is structured into 5 sections. As part of the introduction, a review of the agricultural resources in the country has been presented. The methodology for conducting the analysis follows the introduction after which the results is presented and discussed. Section 4 presents a brief description of the recipes for a successful biofuel industry in Ghana after which Section 5 summarises the conclusions.

Agricultural Resources in Ghana

Ghana is administratively divided into ten regions with a total land area of approximately 238,537 sq. km. There are 212 Districts/Municipal/Metropolitan Areas (MMDAs), which increased from 138 in year 2000[1]. A recent population census in 2010 estimates Ghana's population at 24.6 million [14]. A regional population density map is shown in **Figure 1**.

The coastal and southern parts have higher population density than the northern parts of the country. The Greater Accra region which also houses the nation's capital has the highest population density whereas the Northern region has the lowest. The Northern region has an estimated 35 persons per square kilometre with vast uncultivated arable lands. In relation to agriculture, there are six agro-ecological zones in Ghana defined on the basis of climate, reflected by the natural vegetation and influenced by the soil type (**Figure 2**).

[1]Previously there were 138 Districts/Municipal/Metropolitan Areas (MMDAs) in Ghana but these were increased to 170 in 2008. At the end of 2011, 42 new MMDAs were created bringing the total number to 212.

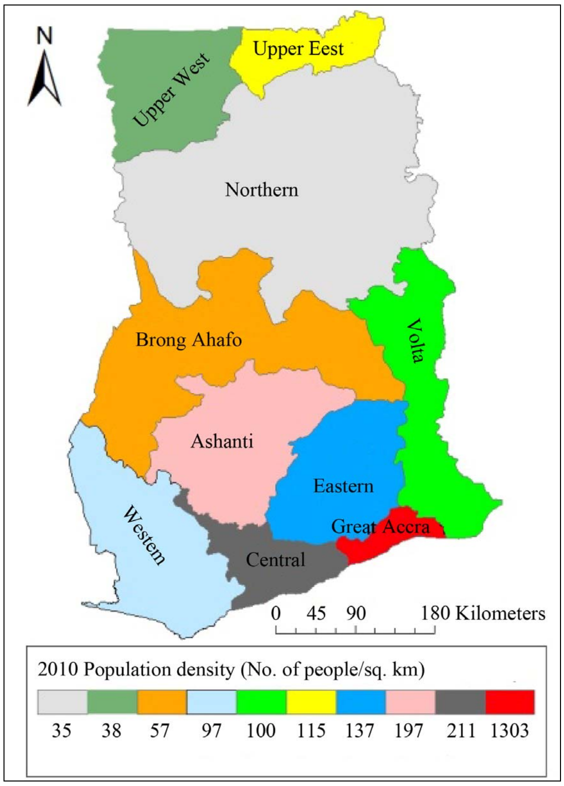

Figure 1. Regional population density map of Ghana for year 2010 [14].

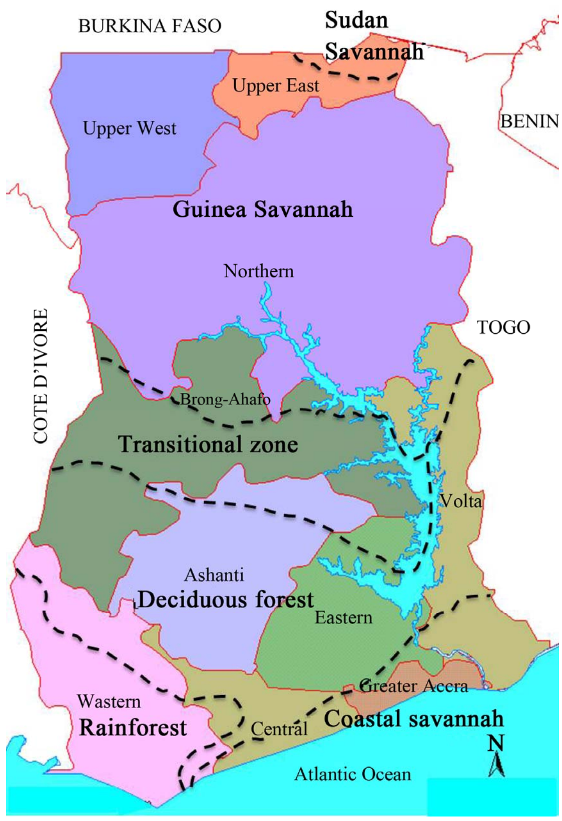

Figure 2. Agro-ecological zone classification in Ghana.

These are Rain Forest, Deciduous Forest, Transitional Zone, Coastal Savannah, Guinea Savannah and Sudan Savannah. The characteristics of the various agro-ecological zones are shown in **Table 1**. Annual rainfall ranges from about 800 mm along the coastal savannah to 2200 mm in the Rain forest. Annual average temperatures range from 26.1˚C near the coast to 28.9˚C in the northern parts of the country. About 155,000 sq. km., approximately 65% of the total land area, is classified as agricultural land area [15]. The agricultural sector is characterized by a large number of dispersed small-scale producers, employing manual cultivation techniques dependent on rainfall with little or no purchased inputs but providing over 90% of the food needs of the country [16]. Farming systems vary with the six agro-ecological zones (**Table 1**). However, certain general features are discernible throughout the country. According to [17], crop production in Ghana is hampered by land degradation, improper field development, use of low-yielding varieties, lack of organised seed production and distribution systems, and inadequate storage structures. Situated in a tropical climate, Ghana has the advantage of growing the most desirable energy crops for biofuel production. **Table 2** shows a summary of key characteristics of some of these crops.

With regards to Food security, 5% of Ghana's population are food insecure. The food security problem exists in all the agro-ecological zones and in both urban and rural areas. There have been many agricultural projects implemented to address the food security problem particularly in relation to stable food crops such as maize, rice, sorghum and soybean. Root and tuber crops such as cassava, yam and cocoyam have also been considered. The government is introducing block farm programmes to make it possible for government sponsored mechanisation and extension services to cover large number of farmers. The Ministry of Food and Agriculture has also set up the National Food Buffer Stock Company (NAFCO) to ensure food security and to insulate farmers against losses resulting from anticipated increases in production.

2. Methodology

2.1. Crop Cultivation Pattern in Ghana

In 2010, approximately 7.8 million hectares, or 57.6% of the available arable land for agriculture in Ghana was under agricultural cultivation [16] leaving approximately 5.8 million (or 42.4%) which was classified as uncultivated. **Table 3** shows the cultivated area and production of major agricultural crops in Ghana in the year 2010. Potential crops for bioenergy that dominate the land area are maize, cassava, oil palm and sorghum. Other potential crops such as soybean, sunflower, sugarcane and coconut occupy less land areas. Maize is the most cultivated non-export crop in Ghana followed by cassava. In 2010, approximately 1.9 million tonnes of maize was harvested from an area of 992 thousand ha. Maize is produced in all districts in Ghana, making it the most popular food crop in the country. Over 13.5 million tonnes of cassava was produced from an area of 875 thousand hectares in the same year. About 2 million tonnes of oil palm fruit and 0.32 million tonnes of sorghum were produced in 2010 from an area of 360 thousand hectares and 253 thousand hectares respectively. With regards to the trend in the cultivated area of these four crops, the pattern shows a fairly even trend over the last decade, with marginal increase or decrease in some cases (**Figure 3**). There were notable increases in the cultivated areas of oil palm (96%) and maize (39%) and a fairly even trend in the cultivated area for sorghum (**Figure 3**).

Cassava is the dominant food crop in Ghana in terms of production output and has remained so for the last decade (**Figure 4**). It is cultivated in eight of the ten regions in the country. The large production of cassava is partly the result of a cassava improvement programme—the "Root and Tuber Improvement and Marketing Programme" (RTIMP)[2]—supported by the International Fund for Agricultural Development (IFAD) and the Government of Ghana (GoG) through the Ministry of Food and Agriculture. Generally, oil palm cultivation is carried out in varying scales such as smallholder farms, and medium to large-scale plantations. Of the 360 thousand hectares of oil palm cultivated in 2010, 60 thousand hectares were commercial plantations and the rest (over 80%) are small-scale farms scattered over the southern parts of the country [16].

Based on land area already occupied by potential bioenergy crops, four crops namely, maize, cassava, oil palm, and sorghum have been considered in this paper as possible crops for biofuel production in Ghana. Production trends were similar to the area cultivated for these crops. There are notable increases in the production of maize (99.5%), oil palm (81%) and cassava (51%) which corresponds somewhat to the increases in their cultivated area, indicating that there has been little improvement in the yields of these four crops over the period.

2.2. Scenarios Development

Two principal scenarios were adopted in the assessment of feedstock options for biofuel production in Ghana. A percentage of the uncultivated arable agricultural land available in Ghana is dedicated to growing the selected potential bioenergy crops in the different scenarios to

[2]The programme is a follow-up of the Root and Tuber Improvement Programme (RTIP) which was implemented from 1999 to 2005. RTIMP is being sponsored for a period of 8 years (2007-2014) and was expected to be implemented across 60 districts but this has now been scaled up to 90 districts.

Table 1. Characteristics of agro-ecological zones in Ghana.

Zone	Area (1000 ha)	Rainfall (mm/yr)	Length of growing season (days)	Dominant land use systems	Main food crops
Rain forest	750	2200	Major season: 150 - 160 Minor season: 100	Forest, plantations	Cassava, plantain, maize, oil palm
Deciduous forest	740	1500	Major season: 150 - 160 Minor season: 90	Forest, plantations	Cocoa, cassava, plantain, maize, oil palm
Transition Zone	6630	1300	180 - 200	Annual food and cash crops	Maize, cassava, yam, taro (cocoyam), plantain, groundnut, cowpea, maize
Guinea savannah	14,790	1100	180 - 200	Annual food and cash crops, livestock	Sorghum, maize, groundnut, millet, yam, cowpea, maize
Sudan Savannah	190	1000	150 - 160	Annual food crops, livestock	Millet, sorghum, cowpea, groundnut, yam, maize
Coastal savannah	580	800	Major season: 100 - 110 Minor season: 50	Annual food crops	Cassava, maize

Source: [18].

Table 2. Overview of principal biofuel feedstocks.

Feedstock	Conditions for best performance	Fuel yield per hectare of crop (l/ha)
Sugarcane	Up to 1600 m above sea level	5800 l/ha in Brazil, 4000 l/ha for Africa
Corn (maize)	Grows everywhere but often needs irrigation	3000 l/ha in advanced agricultural systems, 700 l/ha for Africa due to poor yields
Sweet sorghum	Dryer tropics and temperate regions up to 2500 m altitude	3000 - 6000 l/ha
Cassava	Tropical climates up to 1000 m altitude	5400 l/ha advanced agricultural systems, 1750 l/ha in Africa due to low efficiency in current production methods
Oil Palm	Humid tropic areas up to 700 m altitude	6000 l/ha in Malaysia, Africa plantations average less than half
Jatropha	Tropical & semi-arid regions at altitudes up to 500 m. Rainfall from as low as 300 mm	400 - 2200 l/ha of pure plant oil

Source: Compiled from [19].

Table 3. Cultivated area and production of major crops in Ghana, 2010.

Crop type	Area harvested 2010 (ha)	Production 2010 (t)	Yield (t/ha)
Cocoa beans	1,625,000	632,037	0.39
Maize	991,669	1,871,700	1.89
Cassava	875,013	13,504,100	15.44
Yams	384,942	5,960,490	15.48
Groundnuts	353,376	530,887	1.50
Oil palm fruit	352,800	2,004,300	5.68
Plantains	327,870	3,537,730	10.79
Sorghum	252,555	324,422	1.28
Cocoyam	205,342	1,354,800	6.60
Rice, paddy	181,228	491,603	2.71
Millet	176,600	218,952	1.24
Vegetables	165,010	818,615	4.9610

determine the resulting biofuel yields. The biofuel produced in the different scenarios is compared to projected petroleum fuel demand for transportation to determine the percentage of fuel it can replace. Crop data used for the assessment was crop production data from the Statistics, Research and Information Directorate (SRID) of

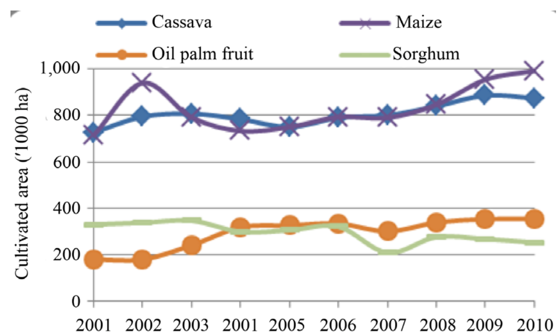

Figure 3. Pattern of land use for selected crops in Ghana. Source: Data from [20].

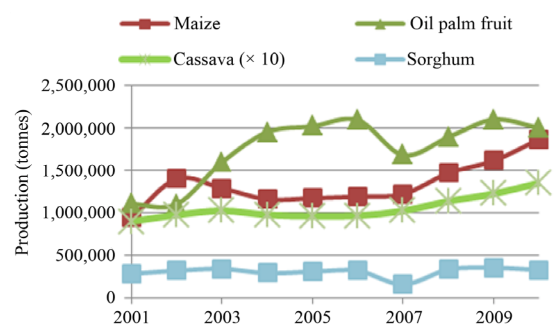

Figure 4. Pattern of production of selected crops in Ghana. Source: Data from [20].

Ministry of Food and Agriculture and also from the Food and Agriculture Organisation. Fuel consumption data and projections were from the National Petroleum Authority and the Energy Commission of Ghana. In the analysis, a portion of uncultivated arable agricultural land in Ghana is dedicated to cultivating the four potential energy crops identified, *i.e.* maize, cassava, oil palm and sweet sorghum in a proportion equal to the proportion in which they were cultivated in 2010. Besides being the most cultivated bioenergy crops in terms of land area, Ghanaian farmers are familiar with their cultivation and the crops are also well suited to the climatic and soil conditions in Ghana. With regards to sorghum, we expect the "sweet sorghum" variety to be cultivated for energy crop purposes. In the first scenario, 2.5% of unused agricultural land (or 144,541 ha) is used to expand the cultivation of these four crops for biofuel purposes. In 2010, approximately 2480 hectares of land was dedicated to these four crops in Ghana. Of this amount, maize and cassava occupied about 75% as shown in **Table 4**. In scenario one, the assumption was made that, 2.5% of uncultivated agricultural land in 2010, which is 144,541 ha is shared among the four crops in the percentages shown in **Table 4** which is the percentage occupied by each of these crops as a total of the area they occupied in 2010. Cultivation is assumed to start gradually and the 2.5% or 144,541 hectares is expected to be fully cultivated in the year 2020. Beyond 2020, no additional land is expected to be allocated to biofuel crops but rather expect further research conducted to improve upon the conservative yields that were used in the initial analysis up to year 2030. The timelines adopted is in line with the Energy Commission's adoption of these dates to realize biofuel blends in transportation fuels in Ghana.

Having allocated land space to each of these crops, biofuel production potential was estimated based on conservative yields achieved in most African countries as reported by [19] and also presented in **Table 2**. These yield figures are based on current agricultural practices in African countries with low irrigation and low fertiliser input. For example, whereas ethanol from maize could yield as much as 3000 litres/hectare in developed agricultural systems, the reported figure for Africa is 700 litres/hectare due to low yields. Also in the case of cassava, about 5400 litres/hectare could be realised in countries such as Thailand but only 1750 litres/hectare is reported for Africa. In order to make a case for research into agronomic improvements, the amount of land space that could be saved is estimated if yields in Ghana were to improve comparable to the current yield in advanced agricultural economies and assuming the same amount of biofuel is to be produced. The resulting biofuel yields are then compared to transportation fuel demand projected for the years 2020 and 2030.

Table 4. Agricultural land allocation to crops in Scenario 1.

Crop	Land area in 2010 (ha)	Fraction of total land area occupied by 4 crops	Portion allocated from 2.5% uncultivated land
Maize	992	0.4	57816.3
Cassava	875	0.35	50589.2
Oil palm	360	0.15	21681.1
Sorghum	253	0.1	14454.1
TOTAL	2480	1	144540.7

The second scenario considered 5% of the uncultivated agricultural land available in Ghana dedicated to growing the identified potential bioenergy crops for biofuel. Scenario 2 differs from Scenario 1 with the addition of jatropha to the four original crops. In the land allocations, 2.5% of the uncultivated land is still allocated to the four crops in the same proportion as in Scenario 1 and an additional 2.5% dedicated to cultivating only jatropha. The 2.5% allocation to jatropha is admittedly high; but this is based on the fact that cassava and especially oil palm are, to a large extent, not cultivated in the northern parts of the country where there is very low population density with large uncultivated lands. The northern parts of the country occupy close to 40% of Ghana's land size. Annual rainfall amounts of 800 to 1100 mm make it feasible to cultivate jatropha in the northern parts of the country. It was therefore assumed that, the bulk of the land dedicated to jatropha in Scenario 2 would be sourced from the northern parts of the country where jatropha is already cultivated on commercial scale.

Again the assumption was made that biofuels produced in both scenarios are to be used locally while the trend in food crop production remains unchanged. It is expected that, improved agronomic practices in the energy crop plantations would trickle down to smallholder food crop programmes which should bring about marginal increases in yields.

3. Results and Discussion

This section presents the results and discussion of the assessment of feedstock options for biofuel production in Ghana.

3.1. Results from Scenario 1

Table 5 presents the results for biofuel production from Scenario 1. Using conservative yields for biofuels from the various crops under consideration, about 303 million litres can be produced from 2.5% of uncultivated agricultural land in Ghana. This is made up of about 219 million litres bioethanol and 84 million litres biodiesel. About 85% of the total land allocated is dedicated to bioethanol crops and only 15% to biodiesel crops. **Table 6** shows the amount of land area that can be saved if the

Table 5. Biofuel production under Scenario 1.

Crop	Land allocated (ha)	Biofuel yield (l/ha)	Biofuel production (l)	Fuel type
Maize	57816.3	700	40,471,410	Bioethanol
Cassava	50997.2	3000	152,931,600	Bioethanol
Sweet Sorghum	14745.5	1750	25,804,625	Bioethanol
Oil Palm	20981.7	4000	83,926,800	Biodiesel
Total	**144540.7**		**303,134,435**	

Table 6. Land area saved with high yields from Scenario 1.

Crop	Desired biofuel production (l)	High biofuel yield (l/ha)	New land area to cultivate (ha)	Land area saved
Maize	40,471,396	3000	13,490	44,326
Cassava	152,991,668	6000	25,499	25,499
Sweet Sorghum	25,804,595	5400	4779	9967
Oil Palm	83,926,858	6000	13,988	6994
Total	**303,194,517**		**57,756**	**86,786**

same amount of biofuel is produced but with high crop yields. In **Table 6**, it is assumed that the country intends to produce the same amount of biofuel (303,194,517 litres) as in **Table 5** but invests in agronomic research that improves yields comparable to the current levels in advanced agricultural economies. It also further takes into consideration, the fact that, high agricultural productivity is achieved with inputs that enhance crop growth and with irrigation schemes where necessary that ensure that crops are not rainfall dependent. Using yield figures from **Table 2**, the targeted biofuel is produced with 57,756 hectares of land and saves over 86,000 hectares of land space in the process compared with conservative yields.

3.2. Results from Scenario 2

Table 7 shows biofuel production in Scenario 2 where an extra 2.5% of the land is used for jatropha cultivation alone. In this scenario, about 563 million litres of biofuel is produced in the country. Bioethanol production under this scenario remains at the same level as in Scenario 1, at 219 million litres. However, biodiesel production increases from the original 84 million litres in scenario 1 to 344 million litres. Again in Scenario 2, if the same amount of biofuel mentioned above is to be produced from high yielding crops, the land savings expected is estimated. In this case achieving high yields from biofuel crops would save the country about 113 thousand hectares of land (**Table 8**) which is more than a third of the land used in Scenario 2 for conservative yields. To achieve such high biofuel yields, cassava, oil palm, sweet sorghum and maize yields would have to increase two-fold, three-fold, four-fold and five-fold respectively compared to existing yields.

Table 7. Biofuels production under Scenario 2.

Crop	Land allocated (ha)	Biofuel yield (l/ha)	Biofuel production (l)	Fuel type
Maize	57,816	700	40,471,396	Bioethanol
Cassava	50,997	3000	152,991,668	Bioethanol
Sweet Sorghum	14,745	1750	25,804,595	Bioethanol
Oil Palm	20,982	4000	83,926,858	Biodiesel
Jatropha	144,541	1800	260,173,260	Biodiesel
Total	**289,081**		**563,367,777**	

Table 8. Land area saved with high yields in Scenario 2.

Crop	Desired biofuel production (l)	High biofuel yield (l/ha)	New land area to cultivate (ha)	Land area saved
Maize	40,471,396	3000	13,490	44,326
Cassava	152,991,668	6000	25,499	25,499
Sweet Sorghum	25,804,595	5400	4779	9967
Oil Palm	83,926,858	6000	13,988	6994
Jatropha	260,173,260	2200	118,261	26,280
Total	**563,367,777**		**176,016**	**113,066**

3.3. Fossil Fuel Replacement

Petrol and diesel consumption for the years 2020 and 2030 was estimated using correlation with population growth to determine portions of road transport fuels that can be substituted with biofuel. Demand for petrol and diesel is expected to reach 1.28 billion litres and 1.97 billion litres respectively by the year 2020. This increases to 1.66 billion litres and 2.56 billion litres for petrol and diesel respectively in 2030. **Table 9** shows the percentage of petroleum fuels that can be substituted with biofuel produced in Scenarios 1 and 2. In 2020, there is a potential of replacing 9.3% of overall diesel and petrol demand with biofuel from Scenario 1. In Scenario 2, there is the potential to substitute 17.3% of petroleum fuels. In Scenario 2, Ghana can substitute 17.1% of petrol with ethanol and 17.5% of fossil diesel with biodiesel. In 2030, Ghana would be able to substitute 7.2% of its petrol and diesel consumption in Scenario 1 and 13.3% in Scenario 2.

3.4. Discussion

Ghana's draft bioenergy policy of 2010 [11] aims for the substitution of national petroleum fuels consumption with biofuel by 10% by 2020 and 20% by 2030. If Ghana were to adopt Scenario 1, the country would be able to replace 9.3% and 7.2% respectively by 2020 and 2030.

Table 9. Transport fuel substitution with biofuel from conservative yields.

	Petroleum consumption (l)	Biofuel production (l)	Petroleum replaceable (%)
Scenario 1 (2020)			
Bioethanol/Petrol	1,280,303,721	219,207,635	17.1
Biodiesel/Diesel	1,970,649,110	83,926,800	4.3
Total	**3,250,952,831**	**303,134,435**	**9.3**
Scenario 2 (2020)			
Bioethanol/Petrol	1,280,303,721	219,207,635	17.1
Biodiesel/Diesel	1,970,649,110	344,100,060	17.5
Total	**3,250,952,831**	**563,307,695**	**17.3**
Scenario 1 (2030)			
Bioethanol/Petrol	1,666,282,480	219,207,635	13.2
Biodiesel/Diesel	2,564,749,310	83,926,800	3.3
Total	**4,231,031,790**	**303,134,435**	**7.2**
Scenario 2 (2030)			
Bioethanol/Petrol	1,666,282,480	219,207,635	13.2
Biodiesel/Diesel	2,564,749,310	344,100,060	13.4
Total	**4,231,031,790**	**563,307,695**	**13.3**

In effect, Scenario 1, which uses 2.5% of uncultivated arable land at conservative yield estimates, comes close to meeting the 2020 target but fall short of the 2030 target. A 2.5% of uncultivated land space can only meet EC targets if there is a significant increase in crop yields. For both target years, *i.e.* 2020 and 2030, Scenario 2 presents relatively high percentage replacements. However, in terms of actual energy content, more bioethanol and biodiesel would be required to meet its equivalent petroleum fuel product. This is because the energy content of bioethanol is about two thirds that of petrol and biodiesel has an energy content of about 12% less than petroleum-based diesel fuel on a mass basis [21]. Scenario 2 serve a better option in both target years for meeting the targets of the draft bioenergy policy.

The decision to increase cultivation of certain crops would demand better technological input into the cultivation of crops and in the end, enhance food crop production in the country. Already, existing bioenergy companies in the country are investing into heavy agricultural machinery and agronomic improvements in order to boost their yields and improve on the economics of production. It is therefore anticipated that, the spill over effects would enhance crop yields from small scale farmers as they learn to embrace new and improved variety of crops. Increased agricultural activities, even with high mechanization would create more employment for the country and the extra biofuel could be exported to other countries in the early stages until the infrastructure is ready to support biofuel consumption in Ghana. Presently, the infrastructure for retailing biofuel blends are not in place as biofuel consumption is not mandated by government.

In order to achieve targets of land use, energy and land use regulators, *i.e.* the Energy Commission and Lands Commission, must ensure that regulatory systems are enforced in order to protect the environment and livelihood. A weakened system and/or regulator would expose the system to exploitation and the perceived benefits would not be achieved. Land acquisition guidelines which factors in all stakeholders (and not chiefs alone as the case is presently), should be in place to ensure a wider participation. Representatives of community members as well as district agricultural and planning officers should be actively involved. Once the structures are in place and lands are demarcated, the Lands Commission must ensure that only lands meant for energy crop production are used for the purpose.

The local production and use of biofuel as substitute for fossil-based fuels offers many attractive benefits for Ghana, but they could also impact negatively if not managed properly. Even though a detailed study on the impact of biofuels falls beyond the scope of this paper, there are notable points that must be taken into consideration in any serious biofuel programme of the kind suggested in this paper. The production of biofuel in Ghana presents an opportunity for local and foreign investments in Ghana, as well as offers the opportunity to reduce crude oil import and reduce the country's vulnerability to supply disruptions. Pursuing Ghana's biofuel potentials would boost agricultural and technological development and create jobs that would enhance the quality of life. The cultivation, harvesting and processing of energy crops could create an additional income avenue for farmers especially during the off-season when they are not engaged in any farming activities. Besides the financial savings that biofuel production of this scale may offer the country, there could also be environmental benefits which include the offset of greenhouse gases (GHGs) associated with the burning of fossil fuels. Exactly how much GHG savings would be realised is still debatable as there is no global agreement on the issue as different computing methodologies have yielded different results.

Notwithstanding the benefits, such a large scale production of energy crops for biofuel could bring with it negative socio-economic and environmental implications. First of all, wages and working conditions could be poor [22,23] and jobs may be given to people living outside plantation communities which could create conflicts. There is also the fear of environmental degradation if regulations are not enforced. This calls for effective regulatory and monitoring agencies actively engaged with all stakeholders.

4. Recipe for Success

In order to realise a successful biofuel industry, there is the need for important policy issues to be put in place and for government to support the industry, especially during its nascent stage. Some of the more critical issues include:

4.1. Enactment of Policies and Regulatory Frameworks

Government support, legislation and regulation are critical to a successful biofuel industry in Ghana. Even though Ghana has targets for overall biofuels consumption in the near future, there are no mandates in place for biofuel blends (e.g. E5, E10, B5, B10, etc.) which could discourage investment plans, especially by the private sector. It could also lead to a situation where companies might be forced to export seeds/oil with a justification that there is no mandate for the use of biofuel. In order to succeed in introducing biofuel consumption in larger quantities in Ghana, the Energy Commission must set blending ratios similar to what countries such as Brazil has done. For a programme of this nature, biofuel agencies or parallel organisations should be established to oversee biofuel development programmes. Such an agency would be able to determine the appropriate support that the industry needs through interactions with various stakeholders and identify the needed infrastructure necessary to attract local and foreign investors into the industry. Clear responsibilities for Environmental and Social Impact Assessments (ESIAs) should be given to the Environmental Protection Agency. ESIAs will be crucial for ensuring socio-economic and environmental sustainability of biofuel projects. Strong government regulatory agencies will be required to undertake ESIAs and also to force their implementation. One critical issue here is the mapping of lands for food and energy crops, as well as for other purposes. Land use maps must be prepared to cover all agro-ecological zones in the country using GIS as appropriate, in order to lessen or eliminate exploitation of food crop lands by biofuel producers. Such maps should inform decision makers on which areas in the country must be reserved only for food crop production and which areas could be used for energy crop cultivation. This would go a long way towards ensuring that poor farmers are not deprived of their farm lands in the biofuel boom.

4.2. Support for R & D and Technology Transfer

The process of transferring biofuel technology and expertise involves the flow of knowledge, experience and equipment among different stakeholders, including governments, the private sector, financial institutions, NGOs, research and educational institutions and labour unions [23]. One of the biggest challenges, for biofuels in Ghana, at the moment has to do with achieving high yields from energy crops and this can be done through partnership with the countries that have achieved higher yields in biofuel feedstocks, such as Brazil for sugarcane, Malaysia and Indonesia for oil palm and Thailand for cassava. These countries have already gone through the experimental stages of agronomical development and there are opportunities for Ghana to partner with them to transfer the knowledge acquired to the country. Apart from improvements in feedstock, processing equipment is another important area that needs development. Biofuel plant providers could build plants on a "build-operate-transfer" basis in partnership with Ghana in the beginning. This would bring about improved local capacity to address the technology issue in future projects.

For biofuel technology transfer to be successful, government must be actively involved. Government support for technology transfer may include direct financial incentives, including grants for Research, Development and Demonstration (R, D & D). Policies supportive of international joint ventures would also help provide domestic companies in Ghana with access to intellectual property owned by international companies. With a natural favourable climate for energy crop production, partners in such joint ventures might contribute host sites for demonstrations and first commercial plants, as well as avenues for entering local biofuel markets. R & D support from the research community is needed in developing high yielding energy crops, standards for blending fuels, the development and improvements in production technology and processing, market development and consumer use. It is important that R & D is linked to technology transfer in such a way that it feeds directly into the scale up of biofuel in the country. R & D efforts need to tackle the practical problems encountered by biofuel technology transfer, not just at the technological level, but at all the critical levels as dictated by the experience from the field. An effective R & D programme should really cover Research, Development, Demonstration and Diffusion (R, D, D & D) and the activities should be closely linked with innovation in the market and education both in its formal and informal/non-formal aspects.

4.3. Ensuring Social Equity and Ecological Sustainability

The production of biofuel in Ghana must be done to ensure social equity. Incentives should be provided for the establishment of small scale biofuel conversion technologies in rural communities so that higher-value products may be produced and sold directly from the rural industries. Thus, Prescribed Obligatory Purchases (POPs) requiring private biofuel companies to purchase stipulated percentages of their feedstock or crude oil requirements from local farmers should be enshrined in the national biofuel policy. Another mechanism that could be used to address multiple objectives for the direct benefit of producers at the lowest and local levels is the Biofuel Export Levy (BEL). The objectives of the BEL could include investment in social services, particularly educational and health facilities, in biofuel producing areas; funding for R & D in improving yields of indigenous feedstocks and purchasing of improved feedstock varieties for small-scale local producers. A BEL could be set at a fixed percentage, up to about 10%, of revenues from biofuel exports and this should be explicitly shared among the different objectives agreed for the BEL.

The production and use of biofuel may have serious environmental impacts such as the use of large amounts of water, destruction of forests, reduction in food production and increase in soil degradation. It is important for Ghana to recognise the ecological challenges associated with biofuel and to address these challenges in order to ensure a sustainable industry. In this regard, it is necessary to put in place sustainability standards to address specific environmental and social issues such as soil erosion; damage to water and soil from the application of pesticides and fertilisers; increased use of freshwater sources; ecological impacts of monoculture crop plantations; the loss of biodiversity and wildlife habitat; potential impacts on agricultural and rural incomes; access to biofuel markets by small landholders and indigenous groups; job availability and quality; potential use of child labour; and access to education and healthcare for workers. The residues generated during the harvesting and processing of the crops could be used to produce biogas which can be used as cooking fuels, thereby reducing deforestation and improving public health.

5. Conclusion

Ghana has the potential to cultivate energy crops for biofuel production. In this assessment, two scenarios were used: Scenario 1 had 2.5% of uncultivated arable land dedicated to only four potential energy crops and Scenario 2 builds on Scenario 1 with an additional 2.5% of uncultivated arable land dedicated to only jatropha. The 5% of the uncultivated agricultural land was allocated to the energy crops in the following percentages: 21.2% for maize, 2.5% for sweet sorghum, 18.7% for cassava, 7.6% for oil palm and 50% for jatropha. Using conservative biofuel yields of 700 l/ha for maize, 3000 l/ha for cassava, 1750 l/ha for sweet sorghum, 4000 l/ha for oil palm and 1800 l/ha for jatropha, a 2.5% of uncultivated arable land dedicated to the four crops presented in Scenario 1 would yield 303 million litres of biofuel. Using the same yields in Scenario 1 and adding 2.5% of uncultivated arable land for jatropha cultivation yields 563 million litres of biofuel. The volume of biofuel produced in Scenario 1 could substitute 9.3% of transportation fuels by 2020 and 7.2% by 2030. In the second scenario, Ghana could replace 17.3% of transportation fuels by 2020 and 13.3% by 2030. At such conservative yield, the country would have to dedicate more land to energy crops in order to meet projections for biofuel demand. Other ways of meeting demand are to raise yields of these crops and/or supplement with production from lignocellulosic materials.

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