ANALYSIS OF BIOFUEL PRODUCTION POTENTIAL, THE NIGERIAN CASE

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Overview

Increase in global development of renewable energy sources as sustainable alternatives to the conventional fossil fuels witnessed in recent time is linked to greenhouse gas (GHG) emissions (CO_2 for example); high dependency on imported fossil oil, especially in the developed world; non-renewable nature of fossil fuels; price volatility of petroleum products; instability in the oil producing areas and development of rural economies.

Electricity/heat generation and transport sectors account for nearly two-thirds of the world's total CO_2 emission in 2009 according to IEA (2011), contributing 41% and 23% respectively. Biofuel is expected to play a significant role in reducing the volume of fossil oil and gas being consumed in the transport sector and the associated GHG emissions which result from the production and consumption of fossil oil and gas.

Energy security is a priority for most countries (ESMAP, 2005). However, Nigeria, like other developing countries, and despite being a major oil producer, is plagued by energy insecurity in addition to a long standing food insecurity. NBS (2009) shows that Nigerian population without access to electricity and those that generate electricity through their own generator sets are on the increase, while those that access electricity through the national electricity company – PHCN is declining.

In terms of food security, Akinyele (2009) reports severe mal-nutritional problems in Nigeria while Okolo (2004) reveals that an average food shortage of 3 million metric tonnes per year existed for almost a decade, costing an average of US$200m (about 19% of the national GDP in terms of national expenditures).

Further, Nigeria spent 4% of her GDP (~ US$5bn/year) importing refined petroleum products (RPP) from 2005 to 2009 (NNPCSTAT, 2011), while Nigerian total primary energy supply is dominated by woodfuel, aggravating deforestation, desertification and CO_2 emissions in the country (EIA, 2011, and FAO, 2011b).

To abate these energy and food security problems, the Nigerian government plans to produce bioethanol from her major staple food crops (sugar and starch crops), despite the much-debated impacts of biofuels on food security. This idea, despite the expected benefits, presents a strong dilemma in reconciling energy production from food/feed crops in view of the already existing food insecurity in Nigeria.

However, the available uncultivated arable land (about 54% of the total as at 2008), relatively cheap unemployed labour and appropriate climatic and soil conditions, are the major factors suggesting that a substantial increase in biofuel production can be achieved without compromising food security.

This research therefore employs sectoral energy-food mathematical programming (linear programming -LP and non-linear programming -NLP) models to examine this proposition (- the production of bioethanol feedstocks and staple food crops in different regions of Nigeria), in order to assess how feedstock and biofuel production can contribute to national energy and food security while avoiding associated energy and food insecurity costs, and how it can contribute to rural community development in Nigeria. However, only LP model approach and the results are presented in this paper. NLP modeling approach is still on-going.

Methods

Secondary data support the construction of the programming model, covering the available historic and up to date Nigerian and regional physical and economic farm production data including crop type, yields, prices, labour and input requirements. Nigerian energy, food consumption and nutritional data, were collected through internet screening of recognized international and national official websites and databases such as EIA, FAOSTAT, IMF, World Bank, US nutritional database, NBS, etc.; published relevant literature, journals and personal research visits to the relevant national ministries, agencies and research institutes in early 2012. The LP model was structured and implemented to ensure that the national food demand is first met with domestic food supply (production) prior to the conversion of the remaining energy feedstocks into ethanol – prioritizing food security to energy. It also covered the major staple food and cash crops produced in Nigeria in order to ensure that land is not taken away from other food/cash crops and released to energy-food crops only. The LP model, reflecting the six agro–geographical, administrative and economic regions of Nigeria, the associated farm production environment (techniques and technology) is calibrated to the existing national crop production data, and is specified as given below:

$$MaxZ = \sum_{j=1}^{n} C_j X_j \text{...} (1)$$

such that

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \text{, for all } i = 1 \text{ to } m \text{...} (2)$$

and

$$X_j \geq 0 \text{, for all } j = 1 \text{ to } n \text{...} (3)$$

where

Z = total gross margin from all activities (equivalent to the gross value added of the agricultural sector)

X_j = the level of jth farm activity e.g., hectare of maize grown, $j = 1$ to n activities

C_j = gross margin of a unit of the jth activities ($/ha)

a_{ij} = the quantity of the i^{th} resource required to produce one unit of the j^{th} activity. In other words, the technical coefficients of a production function. Letting m denote the number of resources, then $i = 1$ to m

b_i = the amount of the ith resource available (RHS), (e.g; ha of land).

Results

Preliminary calibration results show that the LP model replicates the existing data in the national database in terms of quantity of food crops produced, amount of land allocated for their production, labour and inputs utilization, indicating consistency of the model. They also reveal that each of the crops except sugarcane have negative shadow prices; with the highest and the lowest being sorghum and cassava respectively, for the south western region (see table 1). This implies that sugarcane is the potential best feedstock to be used for bioethanol production in this region for example, followed by cassava with the least opportunity cost (shadow price - cost to the total gross margin - TGM) among other crops. The negative shadow prices imply that farmers in this region would reduce their achievable TGM by the corresponding shadow price amounts, should they produce and supply additional 1 MT of each of the crops to the domestic market. Most importantly, the overall model results show that given the model specifications and available resource endowments, it is feasible and profitable to achieve self-sufficiency in food production while producing a substantial amount of feedstocks for biofuel production. To be more precise, a TGM of US$327m (and US$319m without ethanol production), 51 ML of ethanol which will substitute about 5 KL of gasoline at 10% E-blending, and save about US$364m/year at US$70.33/L of RPP in addition to about 12,008 MT of CO_2 savings which would have been emitted into the atmosphere if the substituted five thousand liters of gasoline had been directly combusted in a motor engine without ethanol blending.

Table 1, Optimality condition for the regional production/supply constraints of the base model

Region: South West /Crop	*Quantity produced/supplied - X (MT)*	*Shadow Price (USD)*	*Optimality range (Allowable increase and decrease or lower and upper bound limit)*
Maize	707,647	- 444	6,7395 => X <= 707,647
Cassava	7,328,383	-81	541,354 => X <= 2,185,518
Sorghum	24,947	-1,247	25,741 => X <= 24,947
Sugarcane	20,547	0	440,951 => X <= 20,547
Millet	2,703	-491	58,358 => X <= 2,703
Rice	76,733	-157	54,183 => X <= 76,733

Conclusions: Further analysis of data and extensive sensitivity analyses using NLP model are required to establish the conditions most influencing efficient and effective resource use, and to offer policy recommendations.

Keywords: Biofuel, Bioethanol, Energy Security, Food Security, Analysis, LP/NLP Model and Nigeria.

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