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Review Paper

Problems, Prospects and Policy Initiatives of Bioenergy and Agriculture: A Review with Special Emphasis to Ethiopia

[1, 2*]Miftah Fekadu and [1]Tsegaye Bekele
[1]*Hawassa University, WGCFNR, P. O. Box: 128 Shashemene, Ethiopia*
[2]*Central Ethiopia Environment and Forest Research Center, P.O. Box: 30708, Addis Ababa, Ethiopia,*

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Corresponding Author:
Miftah Fekadu
Hawassa University, WGCFNR, P.O.Box: 128 Shashemene, Ethiopia.

Abstract
Bioenergy is a renewable energy obtained from biomasses of recently living plants and animals. Bioenergy and agriculture could be beneficial or destructive depending on feedstock production, and energy technologies. From totally photosynthesized biomass in the world, only 0.4 % is used as food. Globally, biofuel shares 2 % of cropland. Biofuel reduces Greenhouse Gas (GHG) emissions by 10–90 % of fossil fuels. Some scholars attributed the cause for the 2007/2008 food crises was the use of food for biofuel while some others said it was due to poor productivity. In Ethiopia, in 2008, 92% of the energy supply was obtained from biomass. Blending of 10% bioethanol from state owned sugar factories (E10) has been practiced from 2011- 2013 that saved 30.2 million $USD. Therefore, the problems of bio-energy and agriculture are low productivity on limited land and water while the prospects are economic and social development. Bioenergy has been supported by global and national policies. However, bioenergy has low energy density, and high cost when compared with fossil fuels. Therefore, to maintain the sustainability of bioenergy and agriculture, there should be innovative cost minimization, selection of bioenergy crops, and proper landuse technologies.

Key words: *Biomass, food security, emission, and productivity*

Introduction

Bioenergy is a renewable energy obtained from biomasses (biological products of recently living organisms or their metabolic by-products) (Abbasi, 2010). Agriculture is the art and science of growing and cultivating food plants and animals. Fossil fuels are products from long dead biological materials. Common biomass resources are agricultural crop residues, energy crops, animal manure, agro-industrial food processing wastes, forest biomasses (firewood, charcoal, residues), and municipal solid wastes (Caputo et al., 2005).

The impact of bioenergy on agriculture depends on type and methods of feedstock production, type of energy technologies used and levels of conversion efficiency of power plants and generators. Therefore, the problems and prospects of bioenergy and agriculture are determined by locality, agroecology, policy enforcement and land availability, which is difficult to set a universally rule. Accordingly, bioenergy is sustainable in some instance and destructive in other cases (UN Energy, 2007).

The objective of this review is to synthesize the problems and prospects in bioenergy and agriculture by highlighting policy initiatives at different levels in the times of climate change in order to create common understanding among different people who are either opposing or supporting the production of bioenergy, biofuel.

Primary Biomass Productivity and Determinants

All the energy used is obtained from the solar power stored in the form of chemical energy in the biomass of green plants in the form of sugars, starch, fats, oils and other polysaccharides depending on characteristics of the plants. Photosynthetic plants, at the global scale fix 200 billion tonnes of carbon in the form of biomass, which is approximately ten times the energy equivalent used yearly in the world. Some 800 million tonnes (0.4 %) out of the total fixed amount is used as food (Bassam, 2010).

The determinants of biomass accumulation are environmental factors (light, temperature, water, etc.), the genetic structure of genotype and population (genes, enzymes, leaf structure, etc.), and external inputs (fertilizer, irrigation, tillage, etc.). Higher biomass could be obtained in warmer and humid tropical climates (Samson & Chen, 1995) with high potential of production in tropical Africa. The efficiency and productivity determines the sustainability of biomass energy utilization.

Biofuel Contribution and Policy Initiatives

Biofuels in 2009 account for 0.2 % of total global energy and 1.5 % of total road transport fuels consumption. It is projected that production of biofuels, particularly ethanol and biodiesel for use in the transport sector has tripled since 2000 to 2009 and is projected to double again within the next decade and will contribute 5% by 2030, 8% by 2050 of global energy consumption. The increase has been driven largely by policy support measures in the developed countries, seeking to mitigate climate change, enhance energy security, and modernize the rural agricultural sector (FAO, 2009). Ethiopia formulated Bio fuel Development and Utilization Strategy in 2007 as one of the first sub-Saharan country (IISD, 2007; Jumbe et al., 2009) which aimed at guiding the sustainable production of biofuel. This was enforced in the sustainable development goals and targets of UN (2015), by planning to increase the share of renewable energy in the global energy mix by 2030.

Trends of 11 year average share of biomass fuel consumption of different sectors in Ethiopia implied that households consumed 99.6% of all biomass fuels in the last decade (Guta, 2012). According to the International Energy Agency report of 2008, 92% of Ethiopia's energy demand was obtained from biomass source which seems to continue in the foreseeable future with only 15 % of the total population has access to electricity (IEA, 2011). From 2008 onward the annual demand for electricity and petroleum fuel was supposed to grow at 11.6 % and 9.3 % respectively. Moreover, consumption of petrol fuel increased from 1.1 million metric tons in 2001 to 1.9 million metric tons in 2008. The value of the imported petroleum increased around 500% from USD 0.27 billion to USD 1.6 billion in the same period, mainly due to the pick oil in 2008 (MoME, 2008). Therefore, energy security of the country requires production of bioenergy.

Liquid Biofuel Production and Blending Trend in Ethiopia

As reported in the Nationally Appropriate Mitigation Action (NAMA) (FDRE, 2010), Ethiopia has a short term plan of producing 63.36 million liter of bio ethanol and 621.6 million liter of biodiesel starting from 2010 up to 2015 for Road Transport and for household use. The growth and transformation plan of Ethiopia also aspired to produce 1.8 billion liter of liquid biofuels by 2015, consisting of 195 million liter of ethanol and 1.6 billion liter of biodiesel (MoFED, 2010). The Metehara, Fincha and Wonji factories have been producing 8 million liter bioethanol (in 2007), with plans of 83.5 million liter (in 2011) and 137 million liter (in 2015) (ENA, 2010). Although Ethiopia made an attempt to produce ethanol from sugar cane to blend with gasoline in 1979, the lack of commercial production of feedstock, biofuel production delayed nearly 30 years. Metehara and Fincha sugar factories are the two plants engaged in ethanol production. Nile Petroleum entered into an agreement with the Ethiopian Ministry of Mines and Energy (MoME, 2009) to be the sole blending agent for three years. Later, Nile Petroleum, Oil Libya and National Oil Company Plc (NOC) were engaged in the blending business. Ethiopia started to provide a 5 % ethanol and 95 % benzene blended (E5) for the market since 2009. Ministry of Mines and Energy planned to increase the amount of bio-ethanol in the blend to E10 by 2012, E15 by 2013, E20 by 2014 and E25 by 2015. From March 2011 to 2013, E10 is used in Addis Ababa. Some 38.54 million liters of bio-ethanol has been blended with benzene from 2009-2013, thereby enabling the country to save 30.2 million US dollars (WIC, 2013).

Land for Biofuel in Ethiopia

The natural climatic conditions and availability of land and water resources are the main requirements for the production of bioenergy crops globally (UNIDO, 2009). Potentially available land for bio-energy development especially oil crops, in Ethiopia was estimated to be 23.3 million hectares (FDRE, 2007). The biofuel strategy of Ethiopia emphasized the need to facilitate private sector's involvement in biofuels, allocate land, expand existing ethanol and sugar producing factories, and set ethanol blending targets and identify crops (bio-ethanol from sugar beet, sugar cane, sweet sorghum and biodiesel from Jatropha, castor bean and palm trees) (MoME, 2008). However, the strategy was criticized for types of biofuel feedstock (invasiveness and seed regulation), the availability of land (deforestation and land use competition), and the institutional framework (lack of monitoring and public participation). There was also no clear way of improving productivity of biofuel on smallholders' and "marginal" lands in order to create synergy between biofuels and food crops productivity (Portner, 2013). Ethiopia is one of the countries with the highest rate of *"land-grabbing"* (Friis & Reenberg, 2010; Anseeuw et al., 2012). Over 2 million hectares of land was granted to 64 biofuel investors (MoME, 2009) and 82 biofuel investors were registered of which 16 were operational in 2010 (Beyene, 2011).

Potential Biomass Resource Base of Ethiopia

Ethiopia has untapped biomass resources for bioenergy (IEA, 2011) as shown in table 1. There are also biomass residues which are not yet quantified including enset, banana, grasses, fat and other animal residues and wastes. These diverse, bulky raw biomass feedstock such as forestry, agricultural residues, and wastes can be converted into denser and more practical energy carriers for direct heat supply, combined heat and power and co-firing (IEA, 2009).

From table 1, we can argue that the wastes and residues are potential sources for bioenergy production without deforestation and without competition with food production. However, in the absence of alternative resources and technologies, the growing stocks of woody biomass are over utilized. For example, a study conducted by MoARD (2005) showed that Ethiopia exploited 50 million tone/ year of woody biomass over the recommended 45million ton/year while only 8million ton/year of crop residue and cattle dung below the recommended 51ton/year are used. That is 111% of the available woody biomass resources and only 16% of crop residue and cattle dung has been used annually. Therefore, it seems good to process and utilize more wastes and residues in order to alleviate the heavy pressure on forest resources of Ethiopia. Bioenergy like biogas in livestock areas is an alternative to reduce deforestation because of being energy source used instead of firewood (Grimsby et al., 2016). Biogas can also be used as organic fertilizer which can boost agricultural production. Similarly, both biogas and pyrolysis bio-oil can be obtained organic wastes both to produce bioenergy and soil ameliorator. A study conducted in Nigeria showed that combustible renewable energy from waste could contribute to economic growth in appropriate institutional framework (Maji, 2015).

Table 1. Potential biofuel sources of quantified biomass resources in Ethiopia (FAO, 2009; Guta, 2012)

Biomass and residue types	Crop type	Biomass production or area coverage	Current use	Potential use
Agricultural	Coffee and Residues	214,299 tons per year	Briquettes charcoal	BD* &BE**
	Bamboo	469,664ha	Furniture, briquettes, charcoal	BE
	Cotton Stalk and residue	89,000 tons per year	Fiber, fuel	BD
	Chat residue	6,608 tons per year	Charcoal	BD &BE
Energy plants	Jatropha, Castor	23.3million hectare	Oil for biodiesel	BD
Agro-industrial by products	bagasse	700,000ha suitable land for sugarcane	Ethanol	1bil. BE potential
Wood types	Forest	12.2 million ha (11% of total land mass)	Construction and fire wood	BD& BE
	Sawmill residue	25,000tonnes per year	Fuel	BD &BE
	Other woody biomasses	44.65milion ha (41% of total land mass)	Construction and fire wood	BD and BE

Note: BD=Biodiesel; BE**=Bioethanol; BG=Biogas*

Problems of Bioenergy Crop Production

The potential competition of bio energy with agriculture for land, water, fertilizer, and labor must be carefully managed, otherwise causes food insecurity, land and water scarcity, poor productivity in degraded lands, biodiversity and soil loss within the inherited problem of energy density in the biofuel production (IEA, 2009).

Food Security Problems

Food security is a function of available food supply, incomes to purchase food, stability and the nutritional quality of available food. UN Energy (2007) states that liquid biofuel growth has already begun to raise the prices of the world's two leading agricultural feed stocks, maize and sugar cane. Increased demand for biofuels may actually increase production of food commodities, but much of the increased production would be diverted away from use as food. The high demand for food that give rise to higher food prices could increase farmers' net incomes, but also would hinder the ability of net food consumers to afford sufficient nutrition (Faaij, 2008).

The UN Food and Agricultural Organization and the International Food Policy Research Institute reported that biofuels are the main culprit for the rise of 2007 and 2008 crop price. The production of biofuels on lands meant for food crop would result in *"massacres", a total disaster for those who are starving'* (Lederer, 2007). However, biofuel shares only 7 % of global coarse grain use and 9 % of global vegetable oil use. Other studies also argue that commodity price hikes are common in agricultural markets due to a combination of relatively inelastic demand and volatile supply. For example, real (inflation-adjusted) world wheat prices were 15 % higher in 1995 and 1996 than the 2007 price spike. Structural changes of emerging economies including the increase in oil consumption and cyclic changes of adverse weather changes that result in bad harvest affected commodity prices (Bassam, 2010). According to Sustainable Development Commission it was predicted that an increase in oil price from US$50 to US$100 a barrel could cause a 13 % increase in production for crops and 3–5 % for livestock products. Therefore, it is the productivity that could be attributed to price increases of food instead of the use food crops for bioenergy.

Land and Water Availability

The long-term potential for energy crops depends on land and water availability, in addition to choice of crop species and policy targets for renewables (IEA, 2009). However, from the globally estimated 4 billion ha land area suitable for rain-fed crop production, only 1.6 billion is currently in use. Only 2 % of arable land worldwide is used for bioenergy development, while 30 % of arable land left as fallow indicating that land used to grow biofuel raw materials is not the main cause for global hunger. Moreover, farmers in developing countries do not have the financial resources to pay for seed and other agricultural inputs, lack technologies, lack sufficient training and poor integration of indigenous knowledge and thus cannot utilize these available lands intensively and cannot increase productivity. Therefore, low productivity of agriculture in many regions has resulted in unsustainable land use, erosion and loss of soils, deforestation and poverty i.e, land shortage is unlikely to be the major long-term factor in the biomass for food or fuel production (Faaij, 2008).

A case study conducted in Mozambique, Ukraine and Argentina on land availability for bioenergy crops, it predicted that in 2030 there will be land for agriculture and bio-energy crops if there is an increase in productivity per unit area instead of business as usual (BAU) of farming (Figure 1). Figure 1 confirms the UNIDO statement of improving agricultural productivity helps to achieve the high potential deployment of dedicated bio-energy crops (Wicke et al., 2012).

Productivity Problems on Degraded Lands

The land supposed to be used for bioenergy crops is usually abandoned agricultural land and degraded areas (van der Hilst et al., 2013); however, biofuel crops equally need the entire necessary nutrient as agricultural crops. In degraded lands biofuel crops may not be productivity. Similarly, Ethiopia proposed degraded lands for biofuel where the productivity of bioenergy crops such as Jatropha were found to be unproductive. Therefore, the plants to be planted on degraded land need to be studied before large scale plantation development.

Energy Density Problems

Operational vehicles using biofuels travel less distance per tank of fuel. Bio-ethanol contains 33 % less energy per gallon than gasoline and biodiesels contain about 8 % less energy than petroleum-based diesel fuels. The lower energy density has a higher volume and adds transport costs to the already costly biofuels (Gay, 2014).

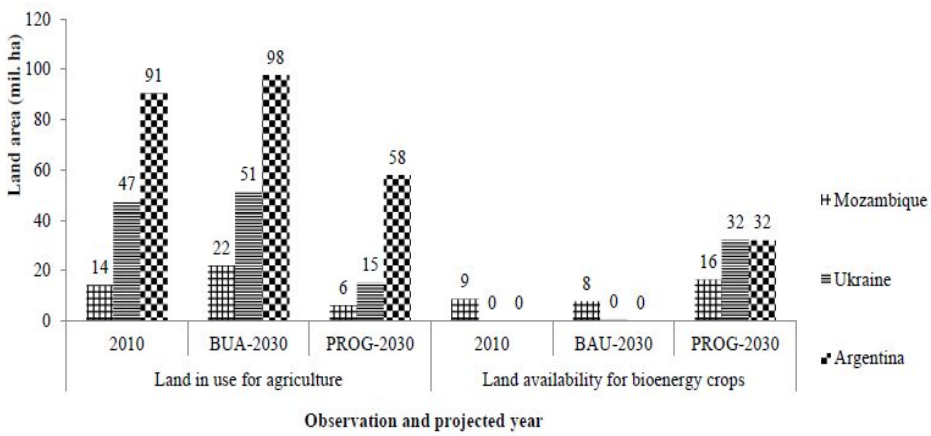

Fig 1. Land for agriculture and bioenergy crops in 2010 and 2030 (van der Hilst et al., 2013)
Note: BAU: business as usual, PROG: New approach, progressive

Energy Balance and Carbon Cycle Problems

Biomass production that uses fossil fuel for farm machinery in land preparation, planting, tending, irrigation, harvesting, storage, and transport; and chemical inputs such as herbicides, pesticides, and fertilizers for processing the bioenergy crop into a usable biofuel the net bio-energy could be smaller. The energy ratio (the quantity of useful bioenergy produced per unit of fossil fuel consumed) of perennial crops is higher than that of annuals because annual crops involve greater use of machinery and a higher level of chemical inputs. For example, some crops (poplar, sorghum, and switch grass) grown in temperate climates have energy ratios of 12 to 16. In tropical climates with good rainfall that use labor energy ratio could be higher while some oil crops in industrialized countries the energy balance is rarely higher than one and in such case the profitability is lower (Kartha, 2006).

The net carbon emission is determined by the methods of production and the type of previous land use allocated for bioenergy production. For example, heat and electricity generation from biomass are better in reducing emission than the transport fuel production. In areas where forests are cleared to make way for new energy crops, the emissions can be even higher than those from fossil fuels (UN Energy, 2007).

Biodiversity, Soil and Hydrological Balances
Bioenergy feedstock production influences surrounding ecosystem depending on the method of planting of monoculture or mixed plantation. In the cases of plantation development, leaving gaps for natural regeneration helps to maintain biodiversity of fauna and flora. Completely harvesting biomass depletes soil nutrient. Bioenergy crops which are optimized for rapid growth and high biomass production consume more water than food crops and natural flora (Kartha, 2006).

Solutions to Land Availability and Food Security
Agricultural and bioenergy crop development requires proper analysis of land cover land use, soil properties, and climate to determine appropriate land use planning to the present and future development. New technologies, improved varieties, and capacity building would gradually increase land productivity over time to meet the growing demand for food, feed, and fiber and biofuel production.

Prospects of Biofuel for Agriculture
The prospects of bioenergy are economic and social development in rural communities including energy diversification, improving living condition, health improvement, and low carbon productions and in urban areas for purification and waste disposal.

Improving Local Infrastructure, Food Production and Social Development
The low agricultural productivity, poverty and food shortage in rural areas in developing countries partly caused by the lack of energy in farming systems. The use of human or animal power for ploughing in the absence of farm machinery resulted in insufficient food production (Kartha, 2006). The development of local biofuels could create biofuel driven farm machineries.

Availability of energy determines the food production process and both are closely correlated. As shown in Figure 2, the lower per capita provision of oil (kilogramme oil equivalent-Kgoe) in Sub-Saharan Africa resulted in lower calorie supply per day while the higher oil supply in countries of Organization for Economic Cooperation and Development (OECD) resulted in higher daily calorie. Therefore, access to modern energy is crucial to increase food production (FAO, 1995b).

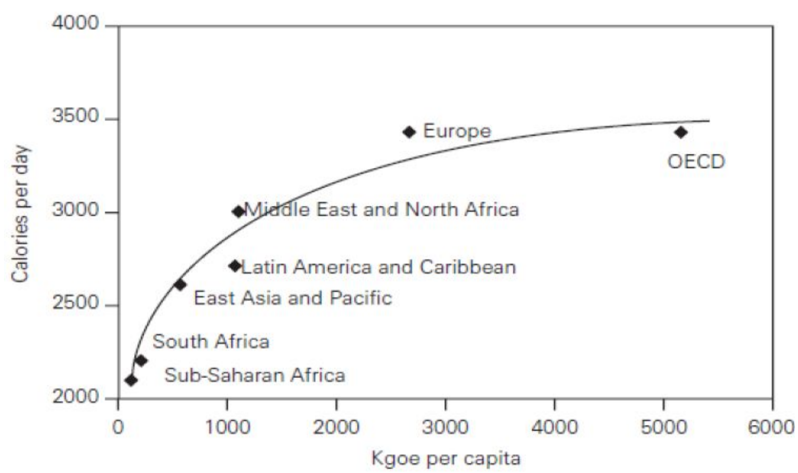

Fig 2. Oil supply as input vs food production as calorie (Bassam, 2002b)

A study conducted in Southern Ethiopia (Wolayeta and Gamo Gofa zone) showed that biofuels investments can have a "win-win" outcome that can improve smallholder productivity, food security, and household welfare. Increased biofuels production can increase production of both food cereals and cash crops but decrease livestock feed at different scale in the administrative regions (Gebreegziabher et al., 2014). The cultivation of castor bean (bioenergy crop) improves the income of rural households in terms of employment or out grower scheme, maintains soil fertility by crop rotation, and protect hunger through food storage (Martha, 2012). On the contrary, the poor productivity of castor bean plantation and mismanagement, conflict with local people for low payments as out growers scheme, poor soil fertility, or lack of profitability of the biofuel feedstock resulted in whole failure of biofuel investment in eastern Ethiopia (Land Matrix, 2013; Locke & Henley, 2013).

Health Improvement
Modern bioenergy helps to meet the need of the 1.6billion people worldwide who lack access to electricity in their homes, and the 2.4billion who rely on traditional biomass fuel to meet their energy needs. Improved access to bioenergy could improve indoor air

quality as it avoids open fire and replace kerosene in poor households and could reduce time spent by women on fuel wood collection, improving health and time available for child care and nutrition (FAO, 2009).

Low Carbon Development
Biofuel crops have roles of climatic change adaptation and mitigation of carbon emissions (IPCC, 2007c), if the management is done in such a way that intercrop with agricultural crops or minimal cultivation with no land use change and avoid inorganic fertilizer. For example, in Brazil incentives for the use of biofuels and energy-efficiency programmes reduced carbon emissions (Pew Center, 2002). Biofuels are estimated to reduce GHG emissions by 10–90 % relative to fossil fuels, depending on the type of feedstock and production technology. Emissions reductions are estimated to be smallest (10–30 %) for ethanol from maize in the United States and largest (70–90 %) for ethanol from sugarcane in Brazil and second-generation biofuels. A 22% efficient biomass steam cycle releases 100 grams of CO_2 per kWh electricity, while a 33% efficient coal steam cycle releases 1000 grams of CO_2 per kWh electricity (Kartha & Larson, 2000).

The use of bioenergy reduces carbon dioxide emission by displacing fossil fuel and sequestering carbon by soil and plants. Energy from biomass favors recycling carbon and therefore, low pollution of air and water, low carbon accumulation in the atmosphere (IEA, 2011).

Conclusion and Recommendations
Bioenergy crops become economically, socially and environmental suitable alternative energy sources when they are well designed in such a way that biomass crops species types and production methods are properly selected, local people are benefited, appropriate land uses (such as food production, livestock grazing, and fuel wood gathering) are properly planned and if the cost of energy regeneration is minimized.

There are favorable policy environment for the development of bioenergy and agriculture. Biofuels crops need appropriate management and can be produced as agricultural crops. Moreover, the bioenergy source can be diversified by using municipal wastes and residues. The problems posed by agriculture and bioenergy namely food security, land and water shortage, market instability could be solved by increasing productivity per unit area of land. Lower energy density problem could also be minimized by short distant bioenergy processing firms or industries.

Bioenergy in form of liquid transport fuel, especially biodiesel and bioethanol production potential of many of the indigenous tree species is a new area of study in Ethiopia that require empirical data based on agroecological conditions. It is also important to conduct research on cost minimization from multiple benefits and processing of bioenergy, and synergies of bioenergy technologies such as thermal, chemical and biological methods of biomass conversion.

Supporting biodiesel production in the short term of exempting biodiesel from fuel excise tax and in the long term of selection of low-cost raw materials such as used frying oil are highly important. Moreover, encouraging farmers to produce energy crops on set-aside land, setting subsidy providing agricultural policy and triggering investment on out grower's scheme are some of the methods in introducing bioenergy.

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