Review on the Impacts of Biofuels Production on the Environment

Garba Ibrahim Dakasku, Hassan Ibrahim and Hassan Galadima Kurkushe

Abstract — The global energy sector is currently undergoing transformation from the use of old source of fuel known as fossils fuel to a sustainable fuel known as biofuels. This transformation was as a result of the need to reduce the amount of greenhouse gasses emitted into the atmosphere which consequently causes increase in atmospheric temperature prevailed from the combustion of fossils fuel. Biofuels has been campaign as the avenue to mitigate climate change, energy security and economic development. This review therefore looked at the concept of biofuels, classification of biofuels and the impacts of biofuel production on the environment with particular reference to climate change, water resources and biodiversity.

Index Terms — Biofuel, Climate change, Environment, Energy, Greenhouse gases, Fossils fuels.

1 INTRODUCTION

[39] Defined the term biofuel or bio renewable fuel as a solid, liquid or gaseous fuel that is primarily manufactured from biomass. [28] defined biofuels as fuel that can be used in fuelling internal-combustion engines acquired from natural sources; they are renewable and can sequestrate the carbon dioxide (CO_2) emissions from their combustion through photosynthesis. The increasing interest in a sustainable source of energy, reduction in greenhouse-gas emissions, energy security, and rustic economic development together with increasing fears of the health impacts associated with conventional fuel combustion increase the quest for biofuel production [6]. Biofuels is therefore viewed from the universal perspective as a key for energy security, sustainable future that will mitigate greenhouse-gasses and alleviate rural economic development. The world-leading biofuel producers (e.g. Brazil and United states) increase mandate for biofuel's production [30]. Through expansion and setting target for increase in its production, this mandate for viable source of energy becomes necessary and one of the most persistent concerns of this decade. With continuous decline in fossil-fuel reserves, rising crude oil prices and uncertainties over the impacts of climate change, it becomes necessary to find and promote the use of renewable or alternative source of energy for the future [34].

1.1 Classification of biofuels

[9;6] classified biofuels based on their production technologies as first-generation biofuels, second generation biofuels and third-generation biofuels. This classification is centred on their generation technologies shown in table 1.1 below. Table 1: The first-generation biofuels seem to be unsustainable because of their adverse effects on food production.

Generation	Feed stock	Examples
First-generation biofuels	Food crops: Sugar, cassava, wheat straw, soy bean, or animal fats, wheat, potatoes, grain maize, barley, corn, wood	Bio ethanol (bio alcohols), bio-diesel (vegetable oil), bio syngas (bio gas)
Second generation biofuels	Non-food crops, wheat straw, solid waste, perennial crops like Miscanthus, switch grass, reed canary grass. Corn stalks or rice husks	Bio alcohols, bio oil, bio DMF, bio hydrogen, bio-Fischer- Tropsch diesel
Third-generation biofuels	Algae(cyanobacteria, Chlorella, protothecoses)	Vegetable oil, bio diesel

Source: [17; 39]

2.0 Greenhouse-Gas Emissions/Reductions Potentials of Biofuels

The major drivers of biofuel's production are energy security, rural economic development and most importantly greenhouse-gas reduction from the burning of conventional fossil's [37]. The target for biofuel's production is promoted among countries all over the world but the concerns about the environmental and social problems of biofuel's production grew continuously [16]. A number of recent investigations have revealed that increase in biofuels production may likely cause significant environmental and social problems. The most important reasons behind research on bio fuel production by both developing and developed countries worldwide is the diversification of other sources of energy, which are environmentally sustainable and help mitigate the impact of the changing climate posed by burning of fossil fuels. Studies by [25], point out that land-use conversion caused by expansion in biofuels production may exacerbate greenhouse gas because it results in the discharge of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) which are powerful greenhouse gases that causes climate change. [41] added that biofuels are believed to mitigate climate change by decreasing the amount of greenhouse gases discharged to the atmosphere from the combustion of conventional fuels. At the same time, expansion in the bio energy sector may increase greenhouse-gas emissions through land-use change as farmers may expand their farmland or clear new land to meet biofuels feed stock demand. The climate change mitigation capacity of biofuels depends on the feed stocks, and the agricultural practice involved during cultivation. [31] despite this variation, the life cycle analyses of biofuels in most literatures are not certain in biofuel's overall greenhouse-gas reduction potentials. Nevertheless, aside emissions due to land-use change, biofuels possess greenhouse-gas reduction potentials when compared to fossil's fuels. [13] declared that most life cycle analysis of biofuels usually neglects the biophysical and nitrogen cycle impacts of biofuels, which are of major concern, changes in the vegetation cover due to land-use change for bio fuel production can alter physical constraints such as solar reflectivity and evapotranspiration, which cause variation in temperature among regions around the world and this variation. Consequently, affects the amount of rainfall or the hydrological cycle as a whole. The nitrogen cycle is affected through anthropogenic application of nitrogenous fertilizer and fossils fuels involved during biofuel's production.

Moreover, scholarly research has found that first-generation biofuels (biofuels produced from food crops) can reduce greenhouse-gas emissions by 20-60% when compared to fossil fuel, except for emissions resulting from land use conversion, feed stock transportation and processing [38]. [9] re-iterates that biofuels are promising in terms of climate-change mitigation potential and can reduce over dependencies on fossil's fuels. In addition, research conducted on how to ensure greenhouse gas depreciation by increasing the use of biofuels revealed that potentials of biofuels in lowering the greenhouse-gas emissions is unclear due to the auxiliary material and the required energy inputs, particularly the direct land-use change (deforestation) impacts of biofuel's production. The other is the environmental impact such as loss of nutrient as a result of feed stock cultivation and harvesting including loss of bio diversity [40]. In order to ensure the sustainability of biofuel's production, various organizations and institutions proposed sustainability criteria for biofuel's production [40]. The greenhouse-gas emission or reduction potential of biofuel's production depends largely on the type of feed stock and agricultural practices involved during its production, if problems of direct and indirect land-use change are considered, biofuels will be better than fossil's fuels in greenhouse-gas reduction potentials. However, [30] arguably state that, in reality, bio fuel production from feed stock's production, processing, refining and combustion releases greenhouse gases. [12] cited that biofuel's production from feed stocks such as soybean, sweet sorghum, oil palm intensively reduces greenhouse-gas emissions when compared to fossil's fuels and other feed stocks like corn, maize, which produces higher greenhouse-gas emissions. Research conducted on the life assessment of biofuels shows that land-use change and potential of biofuels in greenhouse-gas reduction or emissions depend on the type of biofuels feed stock, and the energy source used in the production [42; 4]. In an analysis of energy source of different ethanol bio energy refinery options, figure 2.1 below shows variations in the greenhouse-gas emissions of some ethanol bio energy options arrange in order of their ability to reduce greenhouse-gas emissions [42].

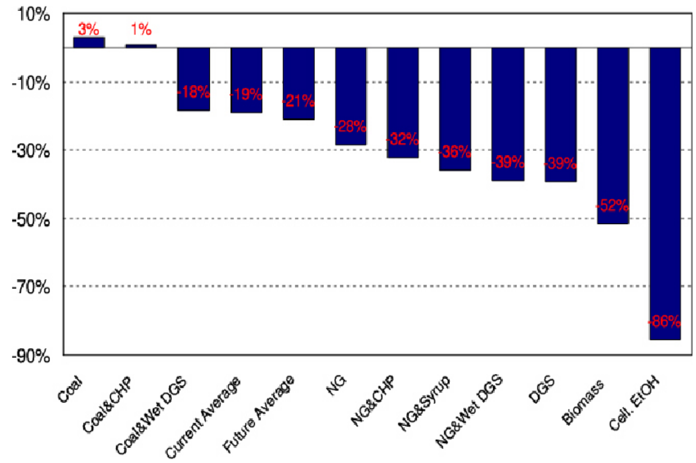

Fig. 2.1 Production to end use GHG emission changes by fuel ethanol relative to gasoline [42].

If the bioenergy source of energy is coal powered, ethanol offers a greenhouse-gas reduction of about 18% averagely, however, if the bioenergy source is plant fuelled and natural gas, the greenhouse-gas reduction ability is between 28 to 39% averagely. [1] suggested the use of energy source from poplar and switch grasses as they have the highest potentials in greenhouse-gas net energy emissions reduction.

Research conducted by [45] on the current trend in biofuels production indicates that increase in global temperature caused by CO_2 is a great concern threatening the world's future. Therefore, protecting the environment is essential and biofuel is the solution because it is a renewable energy resource that has the potentials to reduce greenhouse-gas emissions. The key outstanding driver of greenhouse emissions during Ethanol production is carbon sequestration due to increase in carbon content within the soil which is estimated to be between 159 to 171 g CO_2 eq. Kg-1 especially when the production takes place on a farm land without tillage and emission due to nitrous oxide [29].

Research shows that apart from the emissions of CO_2 and N_2O, there is also an emission of methane CH_4, nitrous oxide N_2O from soil, CO_2 during fertilizer production and the use of machinery during plantation, application of pesticides and harvesting of feedstock is another greenhouse gas emitted in biofuel's production pathways [1;5]. [39] claims that replacing fossil's fuels with renewable-energy source such as biofuels can reduce about 23% greenhouse gas related emissions. Research conducted by [45] point out that the greenhouse-gas reduction ability of corn ethanol depends largely on the cultivation and production process, it reduction ability is about 2% when compared to fossil's fuels if the cultivation and production processes are under a controlled system. [31] also added that in the life cycle breakdown of greenhouse-gasses of ethanol, 35-65% of the emissions come from the production process, and the 35-63% is from the bio refining processes. Ethanol produced from sugar and starchy crops require high inputs of fertilizer, which is an additional source of emission, and they have net emissions rather than being neutral [26]. [7] on the life cycle greenhouse gas emissions and balance of palm methyl ester biofuel from palm fatty acid distillates was found to have greenhouse-gas reduction potential's ratio of more than 80 per cent. [3] argues that the expansion in the bio energy sector will adversely affect the ecosystem through loss of habitat, land-use change for biofuel feed stock production and consequently, lead to greenhouse-gas emission. [33] arguably note that under controlled agricultural practice (without land-use change that causes loss of soil carbon) biodiesel produced from first-generation biofuel crops has the ability to provide 40 to 60% greenhouse gases saving when compare to fossil's fuels. [38] disclosed that the amount of greenhouse gas released to the environment through the use biofuels has been an issue of great concern on climate-change mitigation. Recent increase as the number of scientific findings has begun to change people's hope over the sustainable use of biofuels in reducing greenhouse-gasses considering the use of conventional fuels in biofuel's lifecycle. Among the first-generation biofuels, biodiesel obtain from soy bean has greenhouse-gas reduction and energy-saving potentials of about 41% and 93% respectively relative to fossil's fuels. Whereas bio ethanol obtain from corn possesses greenhouse-gas saving of about 12% due to the use of fertilizer and pesticides in their production [26].

[15] reported that biofuels can replace fossil's fuels because it is sustainable, renewable, has low sulphur content and possesses high combustion efficiency because they are oxygenated compounds thereby producing cleaner emissions. Moreover, [45] state that assuming the emissions from energy input for biofuel's production is considered to be zero due to carbon balance during combustion and growth from the feed stock, there are the emissions of methane, which is another greenhouse gas of great concern because it global warming potential is estimated to be about 25 times that of carbon dioxide.

[27] disclosed that although no energy free of environmental concerns, but corn ethanol has greenhouse-gas reduction potentials of 13% compared to fossil's fuels. Cellulose biomass is therefore required for higher reduction in greenhouse-gas emissions [30] perceptively state that the global greenhouse-gas emissions reach up to 70% between the year 1970 to 2004; biofuels are used to mitigate the emissions because the carbon dioxide release during combustion is sequestered during plant growth. Moreover, ethanol produced from sugar cane exhibits the greatest greenhouse-gas saving of 92% than any other biofuel feed stock.

2.1 Impacts of Biofuels Production on Water Resources

According to [2], water competition from bio energy perspective is divided into: water required for feeds stock production through irrigation, and those needed for bio energy conversion plants and this increase evapo-transpiration. [18] also added that the impacts of biofuel's production on water resources depend upon the cultivation practice and the production region due to rainfall variability among regions around the world. If the production involves irrigation and the use of fertilizer, this leads to underground water degradation and nitrogen loading. [11] arguably state that ethanol produced from cellulose materials under no tillage cultivation practice will reduce pressure on water demand and input. [13] also reported that biodiesel and bio ethanol production requires many amounts of water than production of petroleum, which can cause stress on water resources as well as pollution of water through salinization but with adequate management during feed stock production, biofuels may be sustainable as the future source of fuel [21].

[38] disclosed that commercial production of bio fuel involves the use of agrochemicals as well as fertilizers this eventually cause contamination of water resources; nitrogen loading especially of phosphorus and nitrogen, which trigger eutrophication of water resources and thus affecting aquatic lives. He further asserted that research had shown that most of the contemporary first-generation biofuel crops such as oil palm, sugarcane and maize have an elevated amount of water need and as such cause water shortage, notably in countries that suffer water shortage like China and India; therefore, such crops can be produced under irrigation and in areas that have a high rain downfall in order to get lofty yields. [13] also express similar view that ethanol production from sugar is water intensive, growth in its production may lead to water shortage and contamination. This is often a cause of concern for agricultural activities, water for domestic consumption, especially in rural areas.

Biofuel feedstock requires extreme agrochemicals and fertilizer application, which can be washed down to water bodies thereby potentially affect proper functioning of ecosystems. Similarly, effluents of biofuel production activities are highly toxic with high biological oxygen demand that degrades water quality [21]. it is that estimated that about 1.2 million people are living under the pressure of water scarcity in the world, biofuel's feed stock such as sugar cane is water intensive often cultivated via mono-cultural agricultural practice; further increase in its production may consequently, lead to additional pressure on the existing situation [10].

Production of biofuel impact fresh water quantity and quality through contamination and overexploitation because of the use of agrochemicals and pesticides on biofuel fields, therefore, the use second generation biofuel is suggested as they possesses less pressure on water resources [21] [23]. The water footprint of bioenergy is very high compared to any other form of energy. The variation on the water footprint depends upon the type of crops, climatic condition of the cultivating land area and the agricultural system involved [22]. [44] to achieve the 2020 biofuels target; the water/land requirement is between 32 to 72km2 annually and 5 to 10% of the total water and land requirement respectively.

2.2 Impacts of Biofuels Production on Biodiversity

Another pressing concern regarding biofuel's production is the loss of bio diversity through land conversion for biofuel production which according to [8] will increase both biodiversity loss and climate change and therefore, suggest the cultivation of biofuel's feedstock with less or negative ecological and carbon loss foot print [24]. Study by [42] makes clear that impacts of land-use change may be positive if degraded land is restored for biofuel's production but negative if natural or peat land is converted to the production of biofuels, which will consequently, affect the natural ecosystem.

Studies by [30;36] point out that apart from greenhouse-gas emissions, expansion in biofuel's production may also create land ownership conflicts among local farmers and bio diversity loss, which was estimated to be 277 million tons yearly by 2050 if biofuels were to be used to meet future biodiesel energy demand, which will as well increase pressure on land, further intensification of existing agricultural land and conversion /expansion of rich natural habitat bio diversity land areas. [36]

reported that it was difficult to determine the magnitude of these effects, but to a certain extent, increase pressure on land can directly or indirectly affect bio diversity. Moreover,[24] pointed that biofuel's production may adversely result in bio diversity loss, climate change, pollution, loss of plant and animal species and habitat destruction, which is considered to be of great concern even though the magnitude of the impact depends largely on the land converted.[13] pointed out that further expansion in the biofuel's sector may cause land degradation, loss of habitat and deforestation, integrated agricultural practice can reduce carbon loss and greenhouse-gas emissions. [36] suggest the production of biomass on degraded land that has been estimated to have a total land area of three hundred and eighty-five (385) to four hundred and forty two (472) million hectares of land to meet the world energy need. [20] in the EU, for example, the land requirement for biofuel's production for the year 2020 and 2030 is estimated to between 22 to 60 million hectares. Intensive cultivation of land may further exert excessive pressure on land resulting in loss of soil, water pollution and bio diversity.

Conclusions

Biofuels seems to be a promising, sustainable and eco-friendly source of energy for the future but its production from cultivation to end product raises a lot quest as to whether it can provide a reduction in greenhouse gas emissions. Based on this therefore it is necessary to review its production and technologies involved in biofuels production in order to meet global energy demands without distorting the natural setting of the ecosystem.

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