International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 02 Issue 07 July 2023

DOI: https://doi.org/10.55677/ijlsar/V02I07Y2023-05

Page No : 181-192

Factors Influencing Biofuel Production in Western Kenya

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ABSTRACT: Biofuel production is at the forefront of the agenda of many countries across the globe in the quest to lower greenhouse gas emissions and improve energy access. The increase in oil prices and climate change have been the drivers to ensure the adoption of biofuels. With the global consumption of oil projected to increase, biofuel provides a viable option for a clean, affordable, and climate-friendly source of fuel. However, biofuel production is in Kenya faced with various challenges. Therefore, the study sought to assess the factors that influence biofuel production in Western Kenya. The qualitative research design was adopted with both primary and secondary data collected. Data collection was through interviews, focus group discussions, case studies, and a review of secondary data. The results established that there was a link between food security and biofuel production. Factors influencing the production of biofuel in Western Kenya included the lack of a specific national biofuel policy framework that promotes sustainable development and use of biofuels, limited research, insufficient feedstock to increase production, over-reliance on rain-fed agriculture to grow energy crops, inadequate technology and technical expertise and some knowledge among stakeholders regarding the need and importance of biofuel deployment across the country. There is need for alternative sustainable farming methods that can incorporate cane farming and food crop farming to ensure food security, better farming practices to increase the cane yield, and research on consumer attitudes and behaviours towards biofuels to promote the adoption of the technology.

KEYWORDS: Environmental sustainability, Land use change, Renewable energy, Socio-economic sustainability, sugar cane production, food security

Published Online: 25 July 2023

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1. INTRODUCTION

Biofuel production is at the forefront of the agenda of many countries across the globe in the quest to lower greenhouse gas emissions and improve energy access (FAO, 2010). The increase in oil prices and climate change have been the drivers to ensure the adoption of biofuels. With the global consumption of oil projected to increase by 36% by 2030, biofuel provides a viable option for a clean, affordable, and climate-friendly source of fuel (GTZ, 2008). Therefore, many countries view biofuels as part of the solution, which has resulted in a tremendous increase in production over the past years. The production of biofuel is anticipated to be about 222 billion liters by 2021 with bioethanol accounting for 81% and biodiesel 19 % (Sekoai and Yoro, 2016).

Renewable energy plays a key role in cutting down carbon emissions thus a mitigation measure to climate change. The government of Kenya considers the energy sector as a pillar to meet Vision 2030, which is a development blueprint that aims to improve the quality of life of its citizens in a clean and conducive environment, (Ministry of Energy and Petroleum, 2015). With this regard, the government is putting efforts to invest more in renewables to reduce carbon emissions by 30% by 2030 (Bounagui, 2015). The country is endowed with various renewable energy such as solar, wind, geothermal, hydro, and biofuels. There are two common types of biofuels in the country. These include bioethanol and biodiesel.

Biofuels can be produced using either the first-generation pathway or the second-generation pathway. First-generation entails feedstock that is also used as food whereas second-generation biofuels refer to those sourced from non-edible or ligno-cellulosic biomass (HLPE, 2013). The most common types of biofuels are bioethanol and biodiesels. Bioethanol is sourced from sugar crops such as sugarcane, sweet sorghum, and sugar beet or starchy crops such as corn, cassava, and wheat via the fermentation process.

Bioethanol could also be derived from cellulosic biomass, which comprises woody waste from forests, municipal solid waste, and perennial grass such as switch grass. However, the production of bioethanol from cellulosic biomass is complex, leading to no commercial cellulosic ethanol production. The use of sugar crops as feedstock is preferable to starchy crops because they consume less energy during the production process (Mandil and Shihab-Eldin, 2010).

The production of bioethanol in Sub-Saharan Africa (SSA) began in the 1980s (Mitchell, 2011). The common feedstock used was sugarcane and the by-products of sugar (Molasses). Malawi, for example, produces ethanol and blends it with gasoline. Commercial biofuel production in Africa is at the infant stage because most countries lack sustainable policies that support biofuel production. Whilst biofuels could be produced from a range of feedstock, the common types are molasses from sugarcane for bioethanol and jatropha for biodiesel. Additionally, other crops such as cassava and sweet sorghum to be used as bioethanol feedstock and oil palm as biodiesel have viable options though there is little research conducted on its sustainability and feasibility.

African countries are in a good position to benefit from the high demand for biofuels because of the availability of suitable land to grow biofuel crops. About 1 billion hectares in Sub-Saharan Africa have the potential for rain-fed farming. Biofuel provides an opportunity for economic growth, rural development, energy security, and employment creation in Africa. Biofuels, however, account for a small share of the total energy supplied (Mitchell, 2011). Deenanath et al. (2012) reported that some countries including Zimbabwe, Malawi, and Kenya have embraced the technology.

Biofuel production has gained significant attention as a potential solution to address energy security concerns and reduce greenhouse gas emissions. Renewable energy plays a key role in cutting down carbon emissions thus a mitigation measure to climate change. The government of Kenya considers the energy sector as a pillar to meet Vision 2030, which is a development blueprint that aims to improve the quality of life of its citizens in a clean and conducive environment, (Ministry of Energy and Petroleum, 2015). With this regard, the government is putting efforts to invest more in renewables to reduce carbon emissions by 30% by 2030 (Bounagui, 2015). The country is endowed with various renewable energy such as solar, wind, geothermal, hydro, and biofuels. Two common types of biofuels in the country include bioethanol and biodiesel.

In Western Kenya, where agriculture is a key economic activity, the production of biofuels from agricultural feed-stocks presents an opportunity for rural development and energy diversification. Western Kenya is highly populated with an annual average growth of about 2.7% (Lindell and Kroon, 2010). This poses great pressure on natural resources. The increase in population also results in to increase in demand for food, energy, and water. Agriculture is the main economic activity in the region and since agriculture contributes to about 21% of the Gross Domestic Product, more emphasis has been on cash crop farming. The majority of residents cultivate sugarcane, which occupies 68% of the land. Only 32% is left for food crops (Masayi, 2012). Sugarcane is a feedstock for bioethanol and due to the government's urge to adopt biofuels in the country, there has been an emphasis to double the production of bioethanol to meet 10% ethanol-gasoline blend target (Afrinol, 2017).

The government through the Kenya Bureau of Standards (KEBS) authorized 10% ethanol-gasoline blend (Afrinol, 2015). To meet the target of 10% blend, there is need for national bioethanol production to double. The current gasoline consumption stands at 520.000 m^3/year. With this regard, the government has emphasized the deployment of biofuel fuels and conducted more research on their feasibility and sustainability. Various sugar companies in the country are opting to adopt bioethanol production aside from only manufacturing sugar. Mumias Sugar Company, for instance, is leading across the country in sugar production and has established a distillery ethanol plant that supports the production of about 22 Million liters of ethanol yearly (Mumias Sugar Company, 2012).

There are significant concerns worldwide regarding the sustainability of biofuels. These concerns encompass their economic, social, and environmental impacts, despite their crucial role in providing environmental resilience by reducing carbon emissions, promoting energy security, and fostering economic development. Biofuel production can negatively impact food security by increasing food prices and altering income distribution, posing a significant challenge for rural populations (FAO, 2010). This occurs due to competition for land between bioenergy crops and food crops, as well as competition for resources such as fertilizer, water, and labour to enhance yields. Moreover, since many biofuel feed-stocks are also food crops, the food supply chain is affected. Consequently, the rural poor are particularly vulnerable to these effects, as they are predominantly located in rural areas. Additionally, there is encroachment of forests to create more land for expanding bioenergy farming with the growing demand for biofuel. This leads to biodiversity loss, deforestation, and land degradation. For instance, large-scale sugarcane cultivation employs monocropping, resulting in soil fertility loss (Elbehri, Segerstedt, and Liu, 2013).

In Kenya, despite the government's effort to adopt biofuels across the country, some challenges are impeding its full adoption. These include lack of a specific national biofuel policy framework that promotes sustainable development and use of biofuels, limited research, insufficient feedstock to increase production, over-reliance on rain-fed agriculture to grow energy crops, inadequate technology and technical expertise and some knowledge among stakeholders regarding the need and importance of biofuel deployment across the country. The other challenge is the threat of land use change because of competition between land for bioenergy crops and food crops, which could result in food insecurity (Ministry of Energy and Petroleum, 2015). Given the growing demand for biofuels amidst the challenges, this study sought to assess the factors that influence biofuel production in Western Kenya.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in Mumias district is found in Kakamega County in the Western Kenya part of Kenya (Figure 1). The area is located at 0° 20' 11" North, 34° 29' 21" East of western Kenya (Figure 1), (Maplandia, 2016). The mean annual temperature in the region is about 21.6°C. The region has a single rainfall season with an average annual rainfall total of about 1743 mm per year (Climate Data, 2017). The Most suitable crops grown in the region include sugarcane, beans, and maize farming. The main economic activity in the region is agriculture. Sugar cane farming is the main cash crop and maize farming is the staple food done on small scale. Sugarcane farming occupies about 107,622 ha of land which is 68%. The county has the largest sugar company that also produces biofuel (ethanol) namely Mumias Sugar Company. The company has 67,800 hectares of land with nucleus estates occupying 3,800 hectares and the farmers owning 64,000 hectares. The remaining 32% is for subsistence farming by small-scale farmers (Masayi, 2012). The area has a population of 116,358 according to the Kenya National Bureau of Standards (2009) census.

The choice of the area is because the region is known for sugarcane farming and is leading in bioethanol production. Due to concerns to opt for a low-carbon economy, the dynamics of sugar companies in the country have changed intensively to use sugar cane and molasses as a feedstock for bioethanol production. Mumias Sugar Company is situated in the region and has been a key leader in ethanol production (Mumias Sugar Company, 2012). As explained earlier in chapter one (1), as much as most people in the area engage in sugarcane farming, poverty is still a major issue. Based on the information gathered from the secondary sources, the region has had reported cases of food insecurity, land fragmentation, low crop yields, and land use change which provides a foundation for this research in terms of addressing the sustainability of biofuel production.

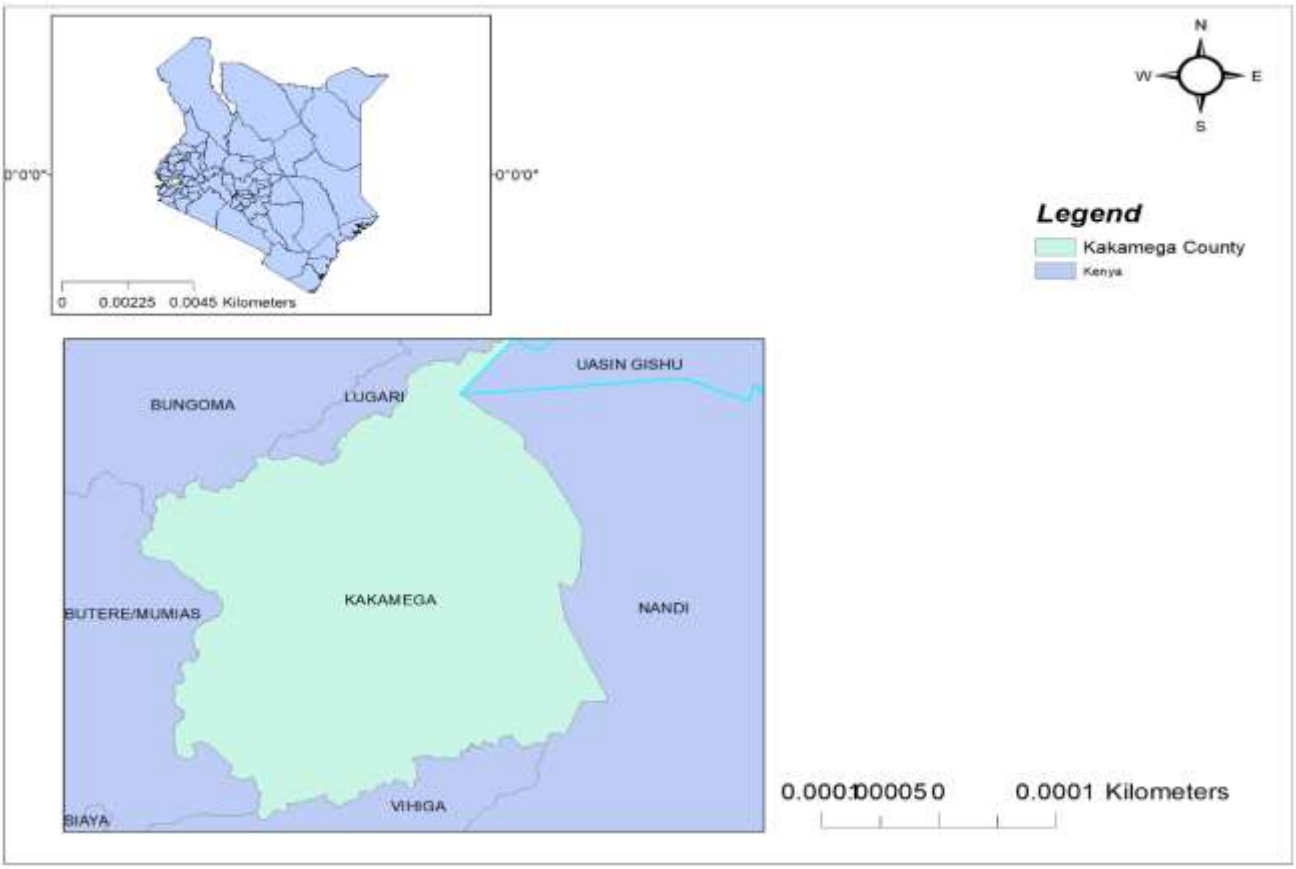

Figure 1. Map of the study area

2.2 Study design

A qualitative research design was used. Kothari (2004) defines research design as procedures or methods used to collect and analyze data to meet the research purpose. According to Creswell (2014), qualitative research involves the description of attributes or phenomena. This research, therefore, adopts a descriptive study by looking into the peoples' views on biofuels in terms of environmental and socioeconomic factors underlying biofuel production, the positive and negative impacts, and their opinion on mitigation measures to ensure espousal of the green energy. The explanatory study is also done by reviewing various case studies to explain the relationship between variables by studying the problem underpinning biofuel production (Saunders and Lewis, 2012). The key variables are the relationship between biofuel production, land use change, and food security.

The inductive research approach was used in this study. This entails the development of a thematic theory based on the results derived from the data collected. It adopts 'bottom up' to measure and observe different phenomena. This helps in the testing of hypotheses based on individual views (Saunders and Lewis, 2012). The approach in this research is incorporated during the interview to acquire information about people's understanding of biofuels, their essence, and their impacts.

The research involves the use of case studies and interviews. A case study is a research strategy that investigates a particular topic of interest in the real-life context from various sources (Saunders and Lewis, 2012). The in-depth literature review is done on various research conducted on the impacts assessment of the sustainability of biofuel production from different parts of the world. Further, biofuel policies in Kenya are also reviewed. The information gathered provides the basis of the research. As a result, a tool for conducting the environmental, social, and economic impact assessment is developed after reviewing various impact assessment tools. The source of the information is derived from, books, reports, and academic papers.

The study adopts thematic theory. This is a research strategy where theory is developed from data generated from interviews or a series of observations (Saunders and Lewis, 2012). The thematic theory relies on the quality of data, which sometimes is subjected to biases from interviewees (Rowlands, 2005). Therefore, to address the challenge, the data collected from the interviewees are coded and categorized to point out important comments from participants.

2.3 Data collection

Primary and secondary data sources were used. The primary involves conducting interviews whereas secondary data is generated from various case studies, academic materials, and reports from relevant organizations that focus on biofuel production. The key part of this study is desk research-based.

2.3.1 Secondary data

Data about sugar cane crop type, land coverage, amount of bioethanol produced, the number of farmers growing sugar cane, and the number of jobs created are gathered from Mumias Sugar Company. In addition, information about food security in the region is acquired from FAO reports and the organization database. The choice of relying on secondary sources to acquire data was because the method is flexible and reliable in giving tangible results.

2.3.2 Primary data

For secondary data, the interview schedule was administered to eight respondents. The respondents included a bioethanol practitioner from Mumias Sugar Company to get data regarding bioethanol, a local sugarcane farmer to provide a general understanding of the benefits and challenges they encounter, an ordinary Kenyan citizen to help provide general information about their understanding of biofuels to triangulate information gathered from interviews and secondary data. Additionally, three master of Energy students from various universities in Kenya were interviewed to gain a better understanding of biofuel from a developing country perspective. Further, a representative from the Ministry of Agriculture (MoA) and FAO to try to understand the agricultural status of the area and the aspect of food security.

2.3.3 Case study

A case study is done in western Kenya on the impact assessment of the sustainable production of biofuels. Based on the review of impact assessment tools in chapter three, the study adopts some of the Global Bioenergy Partnership sustainability indicators for the environmental, social, and economic impact to evaluate the themes of each dimension. Life cycle assessment could be appropriate to assess the sugarcane-ethanol production from cradle to grave, however, the tool was not selected since it is costly, and the period of the research would not allow the completion of LCA.

2.4 Data Management and Analysis

A systematic approach is used to increase the accuracy of the data collected. This involves data categorizing, immersion, processing, searching for patterns, and analysis. Inductive data analysis is done to group raw data into specific themes (Simon, 2011). Relevant information needed for the research is generated. Statistical analysis is also done to explore the contours of the data collected from the interviews and secondary sources. Data is then fed into Microsoft Excel to generate visual data displays that helped in the interpretation. This is in the form of graphs, tables, and charts presenting themes and their connectors.

3. RESULTS AND DISCUSSION

3.1 Bioethanol Production in Mumias

The assessment of bioethanol in western Kenya adopted the Global Bioenergy Partnership sustainability indicators (Table 1). Integration of secondary sources, case studies, and interviews resulted in the selection of themes, which were measured using the indicators.

Table 1. Summary of Themes and Indicators of Bioethanol Production Factors in Western Kenya

Sustainability pillars	Themes	Indicators
Environmental	Land use/land use change	Amount of land used for sugarcane farming
	Water availability	Type of sugarcane farming (rain-fed/ irrigation)
	Biodiversity loss	Amount of area covered by forest
	Soil quality	Type of soil in the area and type of farming practiced (mono-cropping/intercropping?)
Social	Food security	Amount of land for food crop
		Income generated to offset the debate of food and biofuel nexus
	Employment	Access to labour
		Number of people employed by Mumias sugar company
		Number of farmers growing sugarcane
	Poverty	Income generated from sugarcane farming
		Ranking of the county in terms of poverty at the national level
	Energy security	Primary energy by type
		Rate of consumption of petroleum in the transport sector
	Access to technology/infrastructure	Availability of technology/infrastructure for effective production of bioethanol
	Economic viability	Demand for bioethanol in the market
		Amount of bioethanol produced in Mumias
Institutional	Biofuel policies	Availability of biofuel policies

The figure shows there has been an increase in demand for petroleum products. This provides an opportunity for the implementation of technologies to boost biofuel production in Western Kenya (Figure 2).

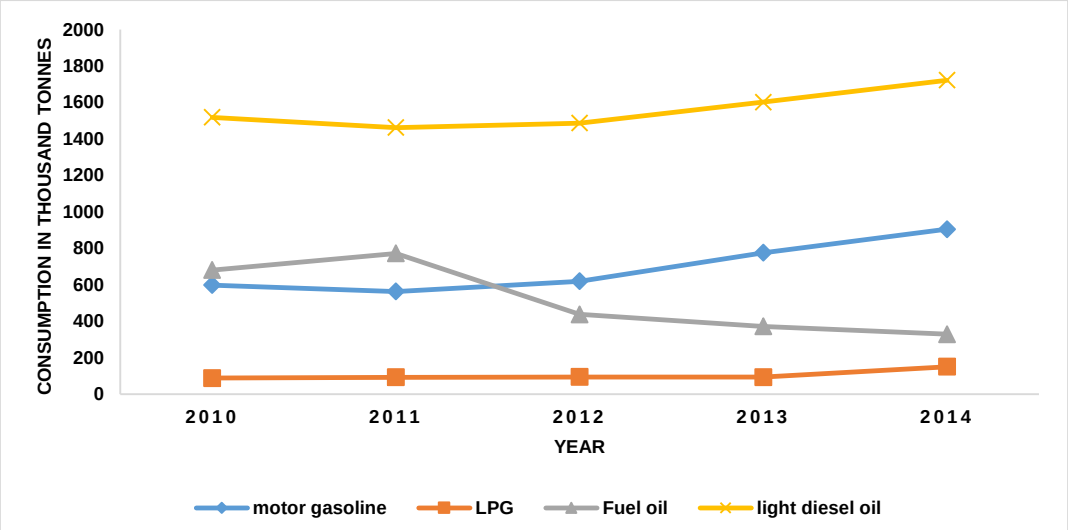

Figure 2. Annual Petroleum Products' Consumption (Data adapted from Energy Regulatory Commission, 2015)

3.2 Factors Influencing Biofuel Production in Western Kenya

3.2.1 Feedstock Availability:

The availability of suitable feedstock is crucial for biofuel production. In Western Kenya, potential feedstock for biofuel production includes crops like sugarcane, maize, sorghum, and oilseeds such as jatropha. The availability and productivity of these feedstocks significantly impact the viability of biofuel production. Identification and availability of suitable feedstock crops, such as sugarcane, maize, sorghum, and oilseeds like jatropha or croton are therefore critical.

Assessment of feedstock productivity, yield potential, and compatibility with local climatic and soil conditions. To ensure feedstock availability, it is therefore important to consider the availability of suitable crops or biomass for biofuel production, yield potential, and productivity of the selected feedstock as well as the land requirements and availability for cultivation. The desirable feedstock characteristics include energy content and composition of the feedstock, moisture content, and impurities, and suitability for specific biofuel production processes

3.2.2 Agricultural Practices:

The agricultural practices employed in Western Kenya can influence biofuel production. Efficient and sustainable farming techniques, such as proper crop rotation, irrigation methods, and the use of organic fertilizers, can enhance feedstock yield and quality. Adoption of sustainable and efficient farming practices, including proper irrigation, crop rotation, pest management, and soil fertility management. Implementation of modern agricultural techniques to enhance feedstock yields and quality.

According to Waswa et al. (2010), before the introduction of commercial sugarcane farming, the farming practice for indigenous food crops employed traditional practices such as intercropping, fallow cropping, and relay cropping. These are environmentally friendly and helps improves soil quality. However, sugarcane farming in the region employs monoculture practice, which has not only resulted in the loss of soil fertility but also contributed to agrobiodiversity erosion.

3.2.3 Land Availability:

The availability of land for cultivating biofuel feedstocks is essential. Adequate land resources are required for large-scale cultivation of crops like sugarcane or jatropha. Land use policies, land tenure systems, and competition with other agricultural activities or infrastructure development can impact the availability of land for biofuel production.

According to Mayasi and Netondo (2014), 68% of the land is under commercial sugarcane farming while 32% is for subsistence farming and other land uses. However, there has been a gradual change of land under sugarcane for the last 34 years and some driving factors have been population growth, settlement, and expansion of towns (Mbayaki et al, 2016). The cultivation of sugarcane on a large scale is diminishing. This is evident by the study which indicated that 76.7% have sugarcane farms of less than three (3) acres and 65% are subdivided into small portions (Were, 2013). Land fragmentation is attributed to cultural factors such as inheritance where land is subdivided between sons; land leasing and population pressure (Waswa et al., 2010). Additionally, an interview with Mumias Company showed that land subdivision has been a major challenge facing cane development, which in turn affects bioethanol production whereby most farmers currently, have a mean of 0.7 acres of land.

According to research done by Were Kweyu (2013), on factors influencing the withdrawal of farmers from sugarcane farming in Mumias western Kenya, it was established that most farmers grow sugarcane on small scale and they need strict supervision from the company staff in order to deliver quality cane to the factory. It has not only, affected the overall yield of the sugarcane, but also contributed to less production of ethanol due to insufficient feedstock.

This is among the reasons why the company has opted to import molasses from neighboring countries to meet the needed demand. According to Business Daily, (2016), Mumias Sugar Company has been importing molasses from Uganda and Tanzania for the past 8 months due to sugarcane shortage. This continues to slow down ethanol production making the ethanol plant produce a capacity of 120,000 liters a day. The ethanol plant requires 300 metric tonnes of molasses daily to operate optimally.

Discussions with Mumias Company revealed that there is lack of implementation of land development policies to determine the extent to which land is converted for other purposes (Mbayaki et al., 2016). Therefore, land use change has led to slow growth of the bioethanol sector due to inadequate feedstock.

3.2.4 Infrastructure:

The presence of a well-developed infrastructure is critical for biofuel production. This includes transportation networks for the movement of feedstock from farms to processing facilities, storage facilities, and processing plants for biofuel production. The availability and efficiency of infrastructure can affect the overall cost and feasibility of biofuel production.

In terms of infrastructure development in the region, most of the roads are inaccessible, and unreliable, especially in the rural areas resulting to delay in cane delivery to the factory (Kakamega County Government, 2015). According to Mumias Sugar Company, poor transport infrastructure has been a challenge that has affected the cane production in the area.

Advanced technology plays a key role in improving agricultural yield and ensuring efficient production of bioethanol. The company has an ethanol distillery plant, however, inadequate technology in the agricultural sector to boost yields has resulted in insufficient feedstock thus forcing Mumias Company to import molasses leading to declining in the net income and rate of profitability from ethanol production, (Business Daily, 2016).

3.2.5 Policy and Regulation:

Government policies and regulations play a significant role in promoting or hindering biofuel production. Supportive policies, such as incentives, subsidies, and mandates, can encourage investment in biofuel production. Additionally, regulations related to land use, environmental impact assessments, and quality standards for biofuels can influence the industry.

Some critical policies and regulations by the government should revolve around government incentives, mandates, and subsidies. The regulatory frameworks for feedstock cultivation and biofuel production and sustainability criteria and certification standards. Government policies and regulations promoting biofuel production, such as incentives, tax benefits, and subsidies. Legal frameworks governing feedstock cultivation, land use, and environmental sustainability. Supportive policies for investment in biofuel production infrastructure and research and development as well as infrastructure development:

3.2.6 Technological Advances:

Advancements in biofuel production technologies can improve the efficiency and economics of biofuel production. Innovative processes for feedstock conversion, such as cellulosic ethanol production or biodiesel transesterification, can enhance the overall productivity and sustainability of biofuel production.

Availability and development of transportation networks for feedstock collection and delivery to processing facilities. Establishment of storage facilities for feedstock and biofuel. Access to processing plants for biofuel production, including refineries and distillation facilities.

Technology and Research on different conversion pathways (e.g., fermentation, pyrolysis, transesterification), technological maturity and scalability of the chosen process, and energy efficiency and potential for a co-product generation. Advancements in biofuel production technologies, such as efficient conversion processes and innovative feedstock pre-treatment methods

3.2.7 Economic Factors:

The cost of feedstock production, harvesting, and transportation, the capital investment required for processing plants and infrastructure, and market prices for biofuels and competing fossil fuels significantly influence the production of biofuel in Western Kenya. Assessment of domestic and international market demand for biofuels, evaluation of the economic viability and competitiveness of biofuel production in relation to conventional fossil fuels, and pricing dynamics, including feedstock costs, biofuel market prices, and cost-effective distribution channels are thus critical.

The indicator used to measure economic viability was the demand for bioethanol in the market through the review of the various literature. It was established that the rising cost of fossil fuel in the international market has driven policymakers to implement the bioethanol blend program. Sugar millers across the country have supported the move since this could help reduce the country's cost of imports of petroleum products. This has made bioethanol fetch demand in the market. With the particular focus on Mumias Sugar Company, the limited supply of crude oil and concerns about environmental degradation were the drivers behind the initiation of the ethanol distillery plant (Mumias, 2012).

The company started with the production of 100,000 liters of ethanol during the commencement of the project in 2012 and there has been an increment in that, by 2016 it produced 12.4 million liters. This is shown in Figure 3.

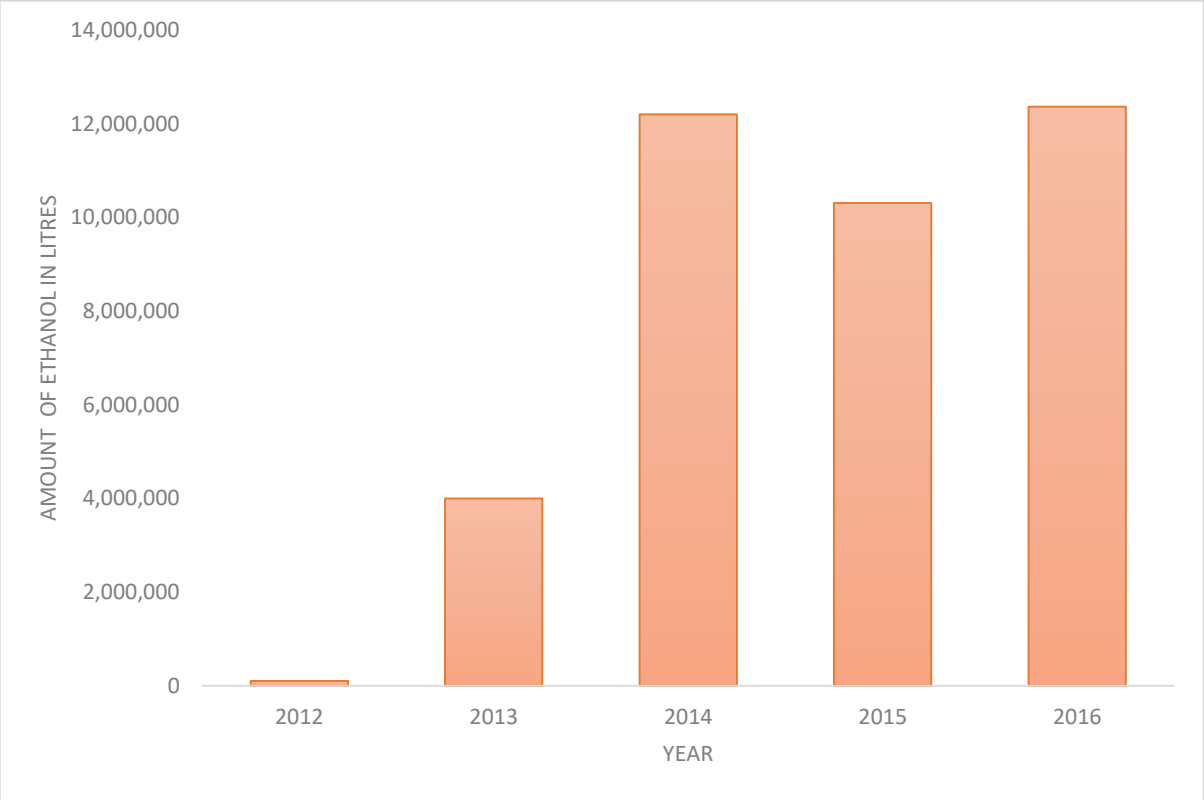

Figure 3. Annual Ethanol Production (Litres) by Mumias Company (Data sourced from Mumias Company)

From the interview with Mumias Company, the decline in ethanol produced in 2015 as shown was attributed to inadequate feedstock thus forcing the company to import molasses from the neighbouring country. This is the main challenge preventing the company from meeting the target capacity of 22 million liters annually. However, the market opportunity for bioethanol is large in terms of demand and profitability. This is due to the availability of ethanol blend (E10) authorized by the Kenya Bureau of Standards. The current gasoline consumption is about 520.000 M3 /year which does not meet the demand. To comply with the E10 mandate, ethanol production is required to double.

Bioethanol provides a viable option in the market to substitute the use of firewood and charcoal. According to Afrinol (2015), the use of firewood accounts for about 80%, kerosene 15%, and Liquefied Petroleum Gas (LPG) 5%. Additionally, 18 million M3 of wood is needed annually to provide 2.8 million tons of charcoal, and this results in the deforestation of 550.000 ha each year in Kenya. Therefore, because of the wood fuel shortage, the situation worsens. This has driven the country to opt for clean burning ethanol stoves to replace charcoal use. Therefore, looking into the market demand for ethanol, it is clear that ethanol plays a key role in the transport sector (ethanol-gasoline blend) and is economically viable as a clean cooking fuel.

3.2.8 Environmental Considerations:
Greenhouse gas emissions and carbon footprint, land and water use impacts and potential for biodiversity loss or habitat destruction affect the large-scale production of biofuel. The government has regulatory measures which affect the eventual productivity in the region. Evaluation of the environmental impact of biofuel production, including greenhouse gas emissions, water usage, and land use change. Implementation of sustainability standards and certification schemes to ensure responsible and sustainable biofuel production practices. Mitigation strategies to minimize the potential negative environmental effects associated with feedstock cultivation and biofuel processing. It's important to note that the specific context and conditions within Kenya may influence these factors differently. Regular monitoring, data collection, and collaboration between stakeholders can help inform decision-making and promote sustainable biofuel production in the country.

In addition, sugarcane is a water-intensive and thirstiest crop thereby having, a significant impact on the environment (WWF, 2017). In the western part of Kenya; sugarcane farming depends on the rainfall. Due to fluctuations in weather patterns because of climate change, the country experiences natural calamities such as drought and floods, which affect the overall yield thus affecting the amount of bioethanol produced. The reliance on rain-fed agriculture has been a challenge facing the sector hence not sustainable. For instance, according to Mumias Sugar Company, (2012), the dry spells experienced in 2009 and excessive rainfall in 2011 led to a decline in the overall yields and poor cane quality hence, a decline in production.

3.2.9 Research and Development:

Advances in technology and process optimization, genetic improvements in feedstock crops for higher yields and traits, and innovation in efficient and cost-effective conversion methods have boosted the production of biofuel in the region. Research and development efforts focused on improving feedstock quality, enhancing conversion efficiency, and reducing production costs. Collaboration between industry, academia, and research institutions to drive technological innovation and knowledge sharing

4. CONCLUSION

There has been a tremendous increase, in biofuel growth over the years in 2015. In addition, aside from the benefits generated by biofuel production, such as employment creation, and generation of revenue just to name a few, the development of biofuel is coupled with sustainability concerns. From this research, the increase in food prices in 2008, triggered the debate on the nexus between food and biofuel production raising concerns about its sustainability. Focusing on the environmental impact, land use, and land use change was the major impact. Conversion of land from food crop to cash crop in this case sugarcane resulted in the loss of agrobiodiversity and food insecurity. In addition, the increase in population in the region led to land fragmentation, which caused a decline in cane production thus resulting in inadequate feedstock for bioethanol production. The debate between biofuel fuel and food production is supported by the fact that food insecurity is a major issue in the area. Despite the job created by the industry, it was identified that the income generated is not enough to offset food insecurity in the region. Therefore, there is a need for a more focused and joint effort that will encourage investment, and promote bioethanol sustainability and economic development. Furthermore, there is need for alternative sustainable farming methods that can incorporate cane farming and food crop farming to ensure food security, better farming practices to increase the cane yield, and research on consumer attitudes and behaviours towards biofuels to promote the adoption of the technology.

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