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Sustainability of Biofuel Production in Western Kenya: A Case Study of Biofuel Production Mumias Sugar Company

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ABSTRACT: Biofuel is a renewable fuel made from biomass, either in liquid or gaseous form. It can be produced from edible or non-edible sources. Common types include bioethanol, derived from sugar crops like corn and sugarcane, and biodiesel, made from fat and vegetable oil crops such as jatropha and rapeseed. Biofuels are environmentally friendly, promote rural development, and enhance energy security. They are used as a substitute for fossil fuels in transportation, such as blending ethanol with gasoline. Additionally, biofuels can be used for cooking, reducing the reliance on firewood and charcoal in developing countries. Concerns about climate change and the availability of biofuel policies have driven their adoption. However, the increased cost of food in 2008 raised questions about the sustainability of the food-biofuel relationship. This study examines biofuel production in Mumias, western Kenya, to assess its current and future sustainability. The research used a case study approach, with both primary and secondary data used. Interviews were conducted to evaluate the production factors, as well as the environmental, social, and economic impacts of bioethanol production. The findings revealed a connection between food security and biofuel production. Other impacts included changes in land use, biodiversity loss, soil fertility decline, job creation, poverty alleviation, economic viability, and energy security. The study identified drivers for biofuel adoption, such as ethanol blend mandates, as well as challenges, including insufficient funding, inadequate policy implementation, limited feedstock, technology gaps, lack of expertise, and inadequate research. Further studies are needed on sustainable farming methods that combine cane farming and food crop cultivation to ensure food security, improve farming practices to increase cane yield, and study consumer attitudes towards biofuels to encourage technology adoption.

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1. INTRODUCTION

Bioethanol is key in the transport sector, in that, about 10 to 100% of it is blended with gasoline in vehicle engines to improve the performance of the engine. For example, about 85% of ethanol in Brazil is used in blends. Bioethanol is a low-carbon and clean fuel hence reducing carbon emissions. It also has a low sulfur content, thus low sulphur emissions in the atmosphere (Mandil and Shihab-Eldin, 2010). Bioethanol can be used as cooking fuel in African countries thereby acting as a substitute to charcoal and kerosene. This provides a clean energy source resulting in improved health through the reduction in indoor pollution, as well as reducing deforestation (Mitchell, 2011).

On the other hand, biodiesel is a liquid biofuel made from fats and vegetable oil such as rapeseed, soybean, Jatropha, oil palm, and sunflower. Rapeseed accounts for 59% of biodiesel produced globally and it is dominant in Europe. However, the overall yield of biodiesel is lower than bioethanol, (Elbehri, Segerstedt, and, Liu, 2013). According to Mandil and Shihab-Eldin (2010), biodiesel has a lubricating property that improves diesel engine functioning. It can also be blended with diesel in vehicles or used in a pure form in vehicles without infrastructure modification. The use of biodiesel is prevalent across Europe.

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). According to Deenanath, Iyuke, and Rumbold (2012), some countries such as Zimbabwe, Malawi, and Kenya just to name a few have embraced the technology.

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.

In Kenya, bioethanol production began in the 1980s. The common feedstock used in bioethanol production was sugarcane. The objective was to promote a national blending program whose focus was to blend ethanol with gasoline and petrol to be used in vehicles. In the 1990s, the production level declined, and blending was abandoned due to inadequate policy framework, leading to the collapse of the Agro Chemical and Food Corp (ACFC) industry. It was until 2010, that the bioethanol program was revived after the government established biofuel guidelines (Ndegwa, Moraa, and Liyama, 2011). 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. 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).

In Western Kenya, where agriculture is a key economic activity, the production of biofuels from agricultural feedstocks presents an opportunity for rural development and energy diversification. However, about 60% of the population in the region lives below the poverty line because of high unemployment rates, (Kwaho, 2012). This is critical since the county was ranked as the poorest in the country according to Daily Nation (2014). Therefore, most farmers prefer sugarcane farming for income generation that enable them meet their basic needs. However, there have also been reported cases of delayed payment, underpayment, and inadequate information regarding sustainable sugarcane farming (Lindell and Kroon, 2010). Instead of economic activity improving the well-being of its citizens, it has resulted in increased levels of poverty. Assessing the sustainability aspects of biofuel production in Western Kenya, considering environmental, social, and economic factors is thus critical.

According to Afrinol (2015), the government through the Kenya Bureau of Standards (KEBS) has authorized 10% ethanol-gasoline blend. 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 annually. With this regard, the government has emphasized the deployment of biofuel fuels and conducted more research on their feasibility and sustainability. The sustainability of biofuel production in Western Kenya relies on a comprehensive approach that addresses environmental, social, and economic aspects. Mitigating environmental impacts through responsible land use, water management, and sustainable agricultural practices is crucial. Social sustainability can be achieved by promoting inclusive development,

Despite the government's effort to adopt biofuels across the country, some challenges are impeding its full espousal. 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). This research, therefore, explores the economic, social, and environmental sustainability of biofuels in Western Kenya, particularly in Mumias District.

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 (Maphill, 2013)

2.2 Study design

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, 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.

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.

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.

For secondary data, the interview schedule was administered to eight respondents (Table 1). 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.

Table 1. Interview Respondents List

Respondent	Position	Role
A	Bioethanol practitioner (Mumias Company)	Source data about the amount of bioethanol produced, demand for bioethanol, land utilized for sugarcane farming, number of jobs created, number of farmers growing sugarcane, and challenges faced in the deployment of ethanol
B	Representative Ministry of Agriculture (Kakamega County)	The situation of availability of Food in the region and agricultural status
C	Food Agriculture Organisation Staff	The situation of availability of Food in the region and agricultural status

D	Mumias sugarcane farmer	Sugarcane farming in the Mumias area
E	Environmental Studies (Community development) student	Perception of Biofuel in Kenya
F	MSc. Student (Kenya)	Perception of Biofuel in Kenya

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.

2.5 Ethical consideration

The interviewees were assured of their confidentiality including their personal information. The interviewer asked for consent from the interviewee before doing the interview. The responders were also informed about the purpose of the research which is for academic purposes. Their role in the research was also clarified. This enabled them to provide valid information and participate voluntarily without any suspicions. This also reduced instances of biases and ensured successful data collection.

3. RESULTS AND DISCUSSION

3.1 Biofuel Screening Toolkit

The United Nations developed Biofuels Screening Toolkit to design biofuel projects and evaluate their sustainability. This tool is commonly applicable in developing countries; however, it may guide for measuring the sustainability of biofuels regardless of the location. The biofuel screening toolkit highlights eleven sustainability criteria for assessing the impact associated with biofuel production. The tool uses traffic light approach where green symbolizes no risk, yellow shows potential risks that can be mitigated and red represents high risks that cannot be mitigated (UNIDO,2013). The eleven sustainability criteria are illustrated in Figure 2.

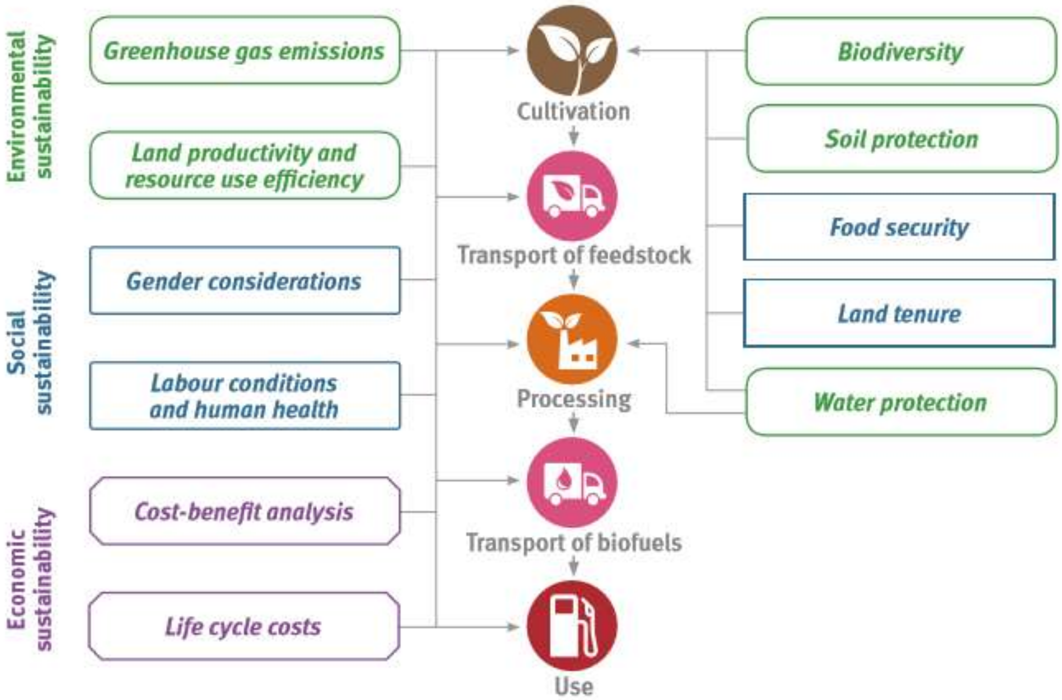

Figure 2. Biofuel Pathway and the Application of Sustainability Criteria (Source: page 11 UNIDO, 2013)

The toolkit covers a wide range of sustainability criteria that is mostly applicable in most sectors. This tool is limited to small-scale projects. However, it provides a rough indication of areas that need to be addressed. The application of the toolkit is narrow especially in large projects because conducting an environmental and social impact assessment for search project is mandatory by law to ensure approval. Therefore, the toolkit could help summarize the findings of EIA/SIA using the eleven sustainability criteria variables.

From the review of various tools and frameworks used in the impact assessment to ensure sustainability, it is vivid that sustainability is a complex task and there is no specific tool to assess the impacts wholly. All aspects of sustainability are not fully incorporated into a chosen tool. It is also clear that sustainability criteria and indicators play a key role in the evaluation of the impacts. Therefore, to conduct an effective impact assessment, the integration of various frameworks and tools is vital. A holistic approach to measuring the impact help cover a wider range of variables thus producing feasible results.

3.2 The Global Bioenergy Partnership Sustainability Indicators for Bioenergy

Global Bioenergy Partnership (GBEP) is a forum, which involves various stakeholders from the national to international level who engage to establish effective policy framework and promote good practices through capacity building. The forum addresses bioenergy development and its contribution to sustainable development. The environmental, social, and economic dimensions are looked into. The other area of focus is on testing suitable methods used in the measurement of GHG emissions and facilitating knowledge transfer, (GBEP, 2011).

Regarding its functions, GBEP developed a set of sustainability-related themes and indicators that assess the impacts of biofuel production. These were developed under the three pillars of sustainable development, which include environment, social and economic. The key themes and indicators that help in conducting sustainable impact assessment are summarized in Figure 3.

PILLARS GBEP's work on sustainability indicators was developed under the following three pillars, noting interlinkages between them:		
Environmental	**Social**	**Economic**
THEMES GBEP considers the following themes relevant, and these guided the development of indicators under these pillars:		
Greenhouse gas emissions, Productive capacity of the land and ecosystems, Air quality, Water availability, use efficiency and quality, Biological diversity, Land-use change, including indirect effects.	Price and supply of a national food basket, Access to land, water and other natural resources, Labour conditions, Rural and social development, Access to energy, Human health and safety.	Resource availability and use efficiencies in bioenergy production, conversion, distribution and end use, Economic development, Economic viability and competitiveness of bioenergy, Access to technology and technological capabilities, Energy security/Diversification of sources and supply, Energy security/Infrastructure and logistics for distribution and use.
INDICATORS		
1. Lifecycle GHG emissions	9. Allocation and tenure of land for new bioenergy production	17. Productivity
2. Soil quality	10. Price and supply of a national food basket	18. Net energy balance
3. Harvest levels of wood resources	11. Change in income	19. Gross value added
4. Emissions of non-GHG air pollutants, including air toxics	12. Jobs in the bioenergy sector	20. Change in consumption of fossil fuels and traditional use of biomass
5. Water use and efficiency	13. Change in unpaid time spent by women and children collecting biomass	21. Training and requalification of the workforce
6. Water quality	14. Bioenergy used to expand access to modern energy services	22. Energy diversity
7. Biological diversity in the landscape	15. Change in mortality and burden of disease attributable to indoor smoke	23. Infrastructure and logistics for distribution of bioenergy
8. Land use and land-use change related to bioenergy feedstock production	16. Incidence of occupational injury, illness and fatalities	24. Capacity and flexibility of use of bioenergy

Figure 3. Summary of GBEP Indicators and Themes (Source page 3 GBEP, 2011)

3.3 Biofuels Production in Africa

The other challenges facing the deployment of biofuels in SSA are inadequate biofuel feedstock, competition for land use, and food insecurity. The increase in population across African countries has led to an increase in food demand, thereby, raising concerns about the sustainability of biofuels considering the feedstock competes with food crops to meet the population needs, (Deenanath, Iyuke and Rumbold, 2012). The Recent rise in food prices has resulted in many African countries restricting the production of biofuel feedstock in the quest to improve food security (Mitchell, 2011). For example, as asserted by Amigun, Musango, and Stafford (2011), there were reported cases of starvation in the rural areas of South Africa where corn was used for biofuel feedstock. As a result, the government had to ban the use of edible feedstock.

Looking into biofuel expansion and food security in Africa, research was conducted by FAO (2010) to assess the viability of biofuel adoption in Tanzania. The key themes were food security, population growth, and poverty. With a particular focus on the agriculture status quo, it was established that cassava and maize provide a potential option for biofuel deployment in the region. However, since these crops are also stapled food, there was anticipated tension to exist in land use change and the decline in food production. Further research was done on the causes of food scarcity in the region. It was recognized that food scarcity in the region though, was attributed to low crop yield and poverty. With this regard, there was a need to promote sustainable agricultural practices and address the issue to prevent the worsening of the situation.

The SSA has the potential of adopting non-edible feedstock. For instance, Ghana is among the active African countries with national biofuel policy that promotes the adoption of biofuels. Due to the continuous depletion of the forest because of mining and lumbering, the government recommended growing Jatropha for biodiesel production. This is because jatropha improves soil quality and restores the ecosystem. Jatropha also withstands harsh climate conditions and is hence suitable in arid and semi-arid regions. However, there have been concerns raised that pertain to benefits and costs. As much as it is non-edible and climate resistant, the cultivation requires fertilizer input, and the overall yields are low which discourages Jatropha farmers from cultivating it. Therefore, the lack of financial viability in the market has led to the decline in private's sector investment (Elbehri, Segerstedt, and Liu, 2013). Government support through the provision of incentive investment is key to encouraging farmers to continue growing Jatropha. Improved variety needs to be developed to increase yields (Mitchell, 2011).

3.4 Sustainability of Biofuel Production in Western Kenya

The assessment of bioethanol in western Kenya adopted the Global Bioenergy Partnership sustainability indicators (Figure 4). Integration of secondary sources, case studies, and interviews resulted in the selection of themes, which were measured using the indicators.

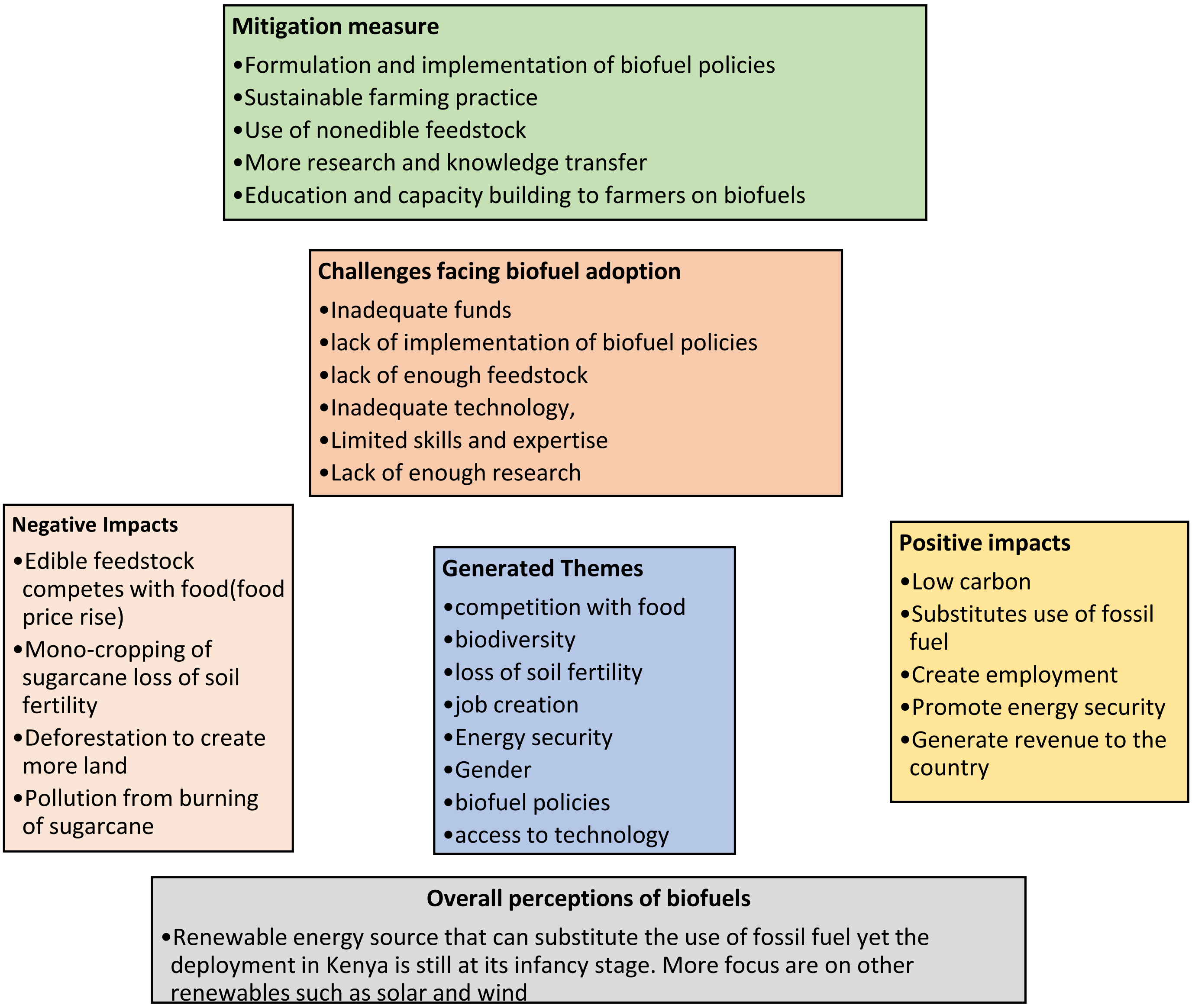

Figure 4. Themes from sustainable biofuel production

Biofuel production has gained significant attention as a potential solution to address energy security concerns and reduce greenhouse gas emissions. In Western Kenya, where agriculture is a key economic activity, the production of biofuels from agricultural feedstocks presents an opportunity for rural development and energy diversification. The review shows the sustainability aspects of biofuel production in Western Kenya, considering environmental, social, and economic factors (Table 2).

Table 2. Summary of Themes and Indicators for Impact Assessment of Bioethanol Production 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	Economic viability	• Demand for bioethanol in the market • Amount of bioethanol produced in Mumias
Institutional	Biofuel policies	• Availability of biofuel policies

3.4.1 Environmental Sustainability

One of the primary environmental concerns associated with biofuel production is land use change. In Western Kenya, the cultivation of biofuel feedstocks, such as sugarcane and jatropha, may compete with land traditionally used for food crops. Proper land-use planning and policies are crucial to prevent deforestation or the conversion of important agricultural lands, which could have negative impacts on food security and biodiversity.

Furthermore, the efficient use of water resources is essential in biofuel production. Water scarcity is already a concern in certain areas of Western Kenya, and the large-scale cultivation of water-intensive crops like sugarcane may exacerbate the issue. Implementing sustainable water management practices, such as drip irrigation and rainwater harvesting, can help mitigate the potential negative impacts.

To ensure environmental sustainability, it is also vital to adopt sustainable agricultural practices in biofuel feedstock cultivation. This includes minimizing the use of agrochemicals, promoting organic fertilizers, and preventing soil erosion through proper land management techniques. By incorporating these practices, the environmental footprint of biofuel production can be reduced.

3.4.2 Social Sustainability

The social dimensions of biofuel production in Western Kenya must be carefully considered. The development of biofuel projects can bring both positive and negative social impacts to local communities. On the positive side, biofuel production can create employment opportunities, enhance rural livelihoods, and contribute to poverty alleviation. Additionally, biofuel production can help diversify income sources for small-scale farmers who may face challenges in traditional crop markets.

However, it is crucial to ensure that the benefits of biofuel production are equitably distributed. Smallholder farmers, who are often the primary stakeholders in biofuel production, should have access to land, resources, and market opportunities. Additionally, mechanisms should be in place to safeguard the rights and welfare of workers involved in biofuel production, ensuring fair labor practices and adequate compensation.

3.4.3 Economic Sustainability

The economic viability of biofuel production is a crucial aspect of its sustainability. Biofuel projects in Western Kenya need to demonstrate long-term economic feasibility to attract investment and ensure their continuation. Factors such as feedstock availability, production costs, market demand, and government policies play significant roles in determining the economic sustainability of biofuel ventures.

Developing strong value chains and establishing efficient processing facilities are essential to maximizing economic returns. By integrating small-scale farmers into biofuel supply chains, a sustainable market can be created, ensuring fair prices and stable incomes. Moreover, exploring opportunities for by-product utilization, such as biogas production from biofuel waste, can further enhance economic viability and overall sustainability.

In summary, the sustainability of biofuel production in Western Kenya relies on a comprehensive approach that addresses environmental, social, and economic aspects. Mitigating environmental impacts through responsible land use, water management, and sustainable agricultural practices is crucial. Social sustainability can be achieved by promoting inclusive development,

4. CONCLUSION

From the findings of this study, it is clear that biofuel plays a key role in reducing carbon emissions, ensuring energy security, and promoting rural development. Climate change concerns and the establishment of biofuel policies have been the driving force for its deployment. There has been a tremendous increase, in biofuel growth over the years, with Brazil and the US being at the forefront and accounting for about 70% of the global supply 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, produced thus resulting in inadequate feedstock for bioethanol production. Despite the job created by the industry, it was identified that the income generated is not enough to offset food insecurity in the region. Sugarcane farmers continue to encounter poverty.

The drivers and barriers of bioethanol production in the region were also explored. The study indicates that the availability of the ethanol blend mandate is the driver that promotes the economic viability of the bioethanol deployment. Additionally, the used ethanol clean stoves are another opportunity to promote bioethanol development since this could substitute the use of firewood which is in high demand and is environmentally unfriendly. However, barriers such as insufficient feedstock, lack of implementation of biofuel policies, inadequate research, poor infrastructure, inadequate technology, limited skills, expertise, and poor farming practices are the factors slowing down the growth of bioethanol.

From this study, Mumias stands at the cusp of numerous opportunities to explore bioethanol production and supply the country with clean fuel as evidenced by the availability of ethanol distillery plants and the continuous increase in bioethanol production by Mumias Sugar Company since 2012. The region also has a favourable climate for both sugarcane and food crops. Therefore, there is a need for a more focused and joint effort that will encourage investment, and promote bioethanol sustainability and economic development.

To ensure food security, the Ministry of Agriculture should collaborate with Mumias Sugar Company to encourage farmers to engage in mixed crop and intercropping farming practices. This will not only ensure food availability in households but also prevent farmers from exiting cane farming, hence resulting in a supply of cane to the factory for bioethanol production. In addition, mixed farming promotes the circulation of nutrients in the soil, which improves soil quality. Regulatory and fiscal reforms should be established to ensure all the stakeholders including the immediate environment are protected and benefit from the biofuel industry.

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